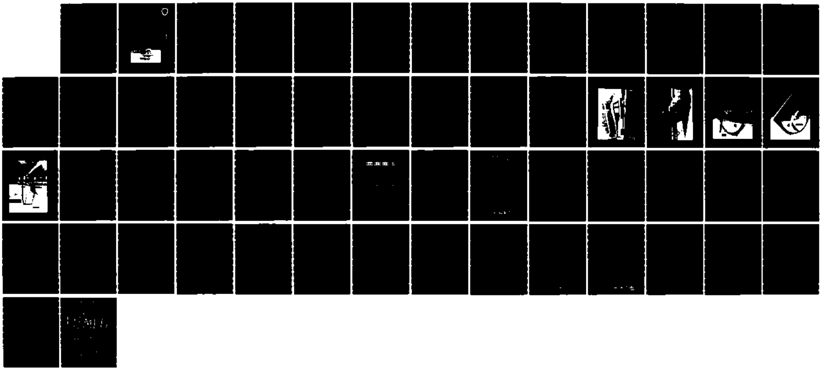
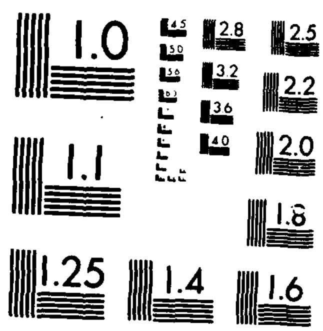
AD-A165 146 GOVERNMENT PILOT EVALUATION OF THE BHTI (BELL HELICOPTER TEXTRON INC) 206..(U) ARMY AVIATION ENGINEERING FLIGHT ACTIVITY EDWARDS AFB CA 1/1

UNCLASSIFIED J I NAGATA ET AL. JAN 85 USAAEFA-83-12 F/G 1/3 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

(12)

USAAEFA PROJECT NO. 83-12

AD-A165 146

GOVERNMENT PILOT EVALUATION OF THE BHTI 206 / RING - FIN TAIL ROTOR

JOHN I. NAGATA
PROJECT OFFICER / ENGINEER

JAMES M. ADKINS
CW4, AV
PROJECT PILOT

JANUARY 1985

FINAL REPORT

USAAEFA

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED.

UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

DISCLAIMER NOTICE

The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

DISPOSITION INSTRUCTIONS

Destroy this report when it is no longer needed. Do not return it to the originator.

TRADE NAMES

The use of trade names in this report does not constitute an official endorsement or approval of the use of the commercial hardware and software.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER USAAEFA PROJECT NO. 83-12	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) GOVERNMENT PILOT EVALUATION OF THE BHTI 206/RING-FIN TAIL ROTOR		5. TYPE OF REPORT & PERIOD COVERED 28 November-7 December 1984 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) JOHN I. NAGATA JAMES M. ADKINS		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US ARMY AVN ENGINEERING FLIGHT ACTIVITY EDWARDS AIR FORCE BASE, CA 93523-5000		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US ARMY AVIATION SYSTEMS COMMAND 4300 GOODFELLOW BOULEVARD ST. LOUIS, MO 63120-1798		12. REPORT DATE JANUARY 1985 13. NUMBER OF PAGES 56
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Government Pilot Evaluation
Ring-Fin Tail Rotor

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Government Pilot Evaluation of the 206/Ring-Fin Tail Rotor Helicopter (Commercial Registration Number N8560F) was conducted at the Bell Helicopter Textron, Inc. test facility at Arlington, Texas between 28 November and 7 December 1984. The test required 9 flights for a total of 6 hours, of which 4.8 hours were productive. The combination of hydraulically boosted directional controls and ring-fin assembly resulted in improved low airspeed handling qualities, particularly in left sideward flight, and approximately 50% increased

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

directional control sensitivity in forward level flight. Testing should be conducted to determine the independent effects of hydraulically boosted directional controls and ring-fin tail rotor assembly on an OH-58C helicopter.

DEPARTMENT OF THE ARMY
HEADQUARTERS, US ARMY AVIATION SYSTEMS COMMAND
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO. 63120-1798

REPLY TO
ATTENTION OF

AMSAV-E

SUBJECT: Directorate for Engineering Position on the Final Report of USAAEFA Project No. 83-12, Government Pilot Evaluation of the BHTI 206/Ring-Fin Tail Rotor

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Engineering position on the subject report. The objectives of this evaluation were to evaluate the Ring-Fin Tail Rotor as a replacement for the standard tail rotor for anti-torque and directional control.

2. This Directorate agrees with the report conclusions and recommendations However, the lateral-directional oscillations discussed in paragraph 23 may have a source other than the ring-fin configuration. USAASTA Report No. 72-20, Handling Qualities Evaluation of the OH-58A Helicopter Incorporating the Model 570B Three-Axis Stability and Control Augmentation System, reports "significant lateral-directional oscillations" when maneuvering an OH-58A with hydraulically boosted directional controls.

3. The dorsal fin was a beneficial contribution to the overall stability of the configuration and should be considered an integral part of the ring-fin installation. Removal of the dorsal fin can lead to high (85%) tail rotor flapping following directional steps in forward flight. For this reason, the 6.5 degree ring incidence without the dorsal fin is not an allowable configuration.

4. In general, the combination of hydraulically boosted directional controls and the ring-fin installation improved both the low speed handling qualities and directional control in forward flight.

5. AVSCOM - Providing Leaders the Decisive Edge.

FOR THE COMMANDER:

~~DANIEL M. McENEANY~~
Director of Engineering

Accession For	
NTIS GRA&I	X
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

TABLE OF CONTENTS

APPENDIXES

INTRODUCTION

BACKGROUND

1. Bell Helicopter Textron, Inc. (BHTI), Fort Worth, Texas began investigation of the ring-fin concept in 1975. The present ring-fin was designed and built in 1983 under contract with the Applied Technology Laboratory (ATL) Ft. Eustis, Virginia. Ring incidence is adjustable and a standard 62-inch diameter Bell 206A tail rotor is used. The ring-fin replaced the standard vertical stabilizer of the Bell 206 helicopter. In May 1983 at the request of ATL, the US Army Aviation Engineering Flight Activity was tasked by the US Army Aviation Systems Command to plan and conduct a Government Pilot Evaluation (GPE) of the Ring-fin Tail Rotor aircraft (ref 1, app A).

TEST OBJECTIVE

2. The objective of the GPE was to obtain limited flying qualities data on the BHTI 206/Ring-Fin Tail Rotor helicopter.

DESCRIPTION

3. The test aircraft (Commercial Registration Number N8560F) was a Model 206 helicopter manufactured by BHTI which incorporated a nodal beam to reduce airframe vibrations and was modified to include a ring-fin tail rotor system. The test aircraft was equipped with single two-bladed, semi-rigid, teetering type main and tail rotors. The Bell 206A Tail Rotor System (photo 1, app B) was modified by placement of a ring shaped shroud around the existing tail rotor (photo 2) and removal of the standard vertical fin. The ring assembly incorporated a removeable dorsal fin. The angle of incidence of the ring center line was nose right relative to the aircraft center line and was ground adjustable. The tail rotor system was further modified by the addition of hydraulically boosted directional flight controls. The aircraft was powered by an Allison 250-C20 engine with an uninstalled intermediate power rating of 400 shaft horsepower (shp) at standard sea level conditions. The main transmission was limited to 270 shp continuous operation and 317 shp for 5 minutes. The aircraft maximum gross weight was 3200 lb. A detailed description of the test aircraft is presented in appendix B.

TEST SCOPE

4. The flight tests for the GPE were flown at the BHTI flight test facility at Arlington, Texas between 28 November and 7 December 1984. The test required 9 flights for a total of

6 hours, of which 4.8 hours were productive. BHTI was contracted to provide and maintain the aircraft and test instrumentation, and process the test data. BHTI also provided a pilot to perform copilot duties. Testing was conducted in accordance with the test plan and within the constraints of the airworthiness release (ref 2, app A). Test conditions are presented in table 1.

TEST METHODOLOGY

5. Flight test data were recorded on magnetic tape by an onboard BHTI instrumentation package (app C). Established flight test techniques were used (ref 3, app A). The test methods and data analysis are briefly discussed in appendix D. A Handling Qualities Rating Scale (HQRS) (fig. 1, app D) was used to augment pilot comments relative to handling qualities. Pilot comments were recorded on cockpit data cards and a cockpit voice recorder.

Table 1. Test Conditions[1]

Type of Test	Average Gross Weight (lb)	Average Density Altitude (ft)	Trim Calibrated Airspeed (kts)	Configuration[2]
Control Positions in Trimmed Forward Flight	3160	3200	34 to 103	Ring fin at 4.5 deg and 6.5 deg, Dorsal ON Ring fin at 6.5 deg, Dorsal OFF
	3180	4200	28 to 102	Ring fin at 6.5 deg, Dorsal ON Longitudinal cg at FS 107.5 (FWD)
Static Lateral-Directional Stability	3120	3700	84	Ring fin at 4.5 deg and 6.5 deg, Dorsal ON Ring fin at 6.5 deg, Dorsal OFF
Maneuvering Stability	3120	3000	84	Ring fin at 4.5 deg, Dorsal ON
Dynamic Lateral-Directional Stability	3100	3700	84 to 104	Ring fin at 4.5 and 6.5 deg, Dorsal ON Ring fin at 6.5 deg, Dorsal OFF
Controllability	3110	3700	84 to 104	Ring fin at 4.5 and 6.5 deg, Dorsal ON Ring fin at 6.5 deg, Dorsal OFF
Low Speed Flight Characteristics	3170	-160	0 to 30 KTAS[3] Rearward 0 to 35 KTAS Sideward	Ring fin t 6.5 deg, Dorsal ON
Simulated Engine Failure	3050	3700	84	Ring fin at 4.5 and 6.5 deg, Dorsal ON Ring fin at 6.5 deg, Dorsal OFF

NOTES:

[1]All tests were conducted at an aft center of gravity FS 111.0 unless otherwise noted, and 394 RPM rotor speed.

[2]Ring incidence was nose right relative to the aircraft center line and dorsal incidence relative to ring center line was 0.0 deg.

[3]KTAS = Knots true airspeed

RESULTS AND DISCUSSION

HANDLING QUALITIES

General

6. Limited handling qualities data were obtained for the Bell 206 helicopter modified to included a ring-fin tail rotor assembly (photos 2 through 5, app B). The directional flight controls were hydraulically boosted and did not include a Stability Augmentation System (SAS), force gradient, or trim feel system. Aircraft handling characteristics were qualitatively and quantitatively evaluated in the configurations shown in table 2.

Table 2. Test Configurations

Ring Incidence[1] (deg)	4.5	6.5	6.5
Dorsal Incidence[2] (deg)	0.0	0.0	Dorsal Removed

NOTES:

[1]Ring incidence is nose right relative to the center line of the aircraft. Ring incidence is not adjustable in flight.
[2]Dorsal incidence is relative to the ring center line.

Test results were compared with data obtained from an evaluation of the Bell 206A helicopter without hydraulic boost or SAS and equipped with standard tail rotor and vertical stabilizer assembly (ref 4, app A). The combination of hydraulically boosted directional controls and ring-fin assembly resulted in improved low airspeed handling qualities, particularly in left sideward flight, and approximately 50% increased directional control sensitivity in forward level flight. Additionally, hovering turns up to 40 deg/sec were easily arrested within 5 deg of a desired heading within 2 sec. A summary of test results is shown in table 3. Testing should be conducted to determine the independent effects of hydraulically boosted directional controls and ring-fin tail rotor assembly on an OH-58C helicopter.

Control Positions in Trimmed Forward Flight

7. The control positions in trimmed forward flight were evaluated at conditions shown in table 1. Tests results are presented in figures 1 through 4, appendix E. Above 45 knots calibrated

Table 3. Test Results Summary

Test	Configuration[1] Ring: 4.5 deg Dorsal: 0.0 deg	Ring 6.5 deg Dorsal: 0.0 deg	Ring 6.5 deg Dorsal removed
Control Positions in Trimmed Forward Flight	40% tail rotor flappings @V_H[2]	20% tail rotor flapping @V_H[2] 6-8% less left pedal required @V_H[2]	40% tail rotor flapping @V_H[2] Similar pedal control required as 4.5 deg ring incidence with 0.0 deg dorsal @V_H[2]
Static Lateral-Directional Stability	Positive and linear directional position		
	Acceptable side force cues		
	Positive Dihedral Effect		Reduced Dihedral Effect
Maneuvering Stability (84 KCAS)	Positive maneuvering stability	Not Tested	
Dynamic Lateral-Directional Stability (1 in. pulse/0.5 sec)	Heavily Damped	Heavily Damped	Reduced Damping
Directional Controllability	Forward Flight: Increased control sensitivity and reduced time to maximum yaw rate compared to the standard Bell 206A helicopter		
	Hover: Hovering turns up to 40 deg/sec are easily arrested within 5 deg of a desired heading within 2 sec		
Low Airspeed Characteristics	Improved low airspeed handling qualities in left sideward flight compared to standard model 206A helicopter		
Simulated Engine Failures (2 second delay) @84 KCAS (Airspeed variation during autorotation 40 to 100 kts)	Minimum 20% directional control remaining during entry and descent. 90 deg heading changes easily performed.		

NOTES:

[1]Ring incidence nose right relative to aircraft center line. Dorsal incidence relative to ring center line.
[2]Maximum level flight speed.

airspeed (KCAS), the longitudinal control position change with airspeed was conventional in that increasing forward control was required with increasing forward airspeed. Between 35 KCAS and 45 KCAS the longitudinal control position either did not change or moved slightly aft (less than 0.25 in.) depending on the ring configuration, but was not objectionable. The lateral and directional control displacements required with increasing airspeed were minimal and adequate control margins existed at all conditions tested. Approximately 6-8% less left pedal was required at maximum level flight speed when the ring incidence was changed from 4.5 deg to 6.5 deg and dorsal fin at 0.0 deg.

Static Lateral-Directional Stability

8. Static lateral-directional stability characteristics were evaluated at incrementally increasing left and right sideslip angles in level flight at 84 KCAS. Test results are presented in figures 5 through 7, appendix E. The directional stability, side force characteristics, and dihedral effect were positive for all conditions tested. For a given right sideslip angle, the dihedral effect, (as indicated by variation of lateral control from trim at zero sideslip) was reduced when the dorsal was removed and ring incidence was increased from 4.5 deg to 6.5 deg. With dorsal ON and ring incidence at 4.5 deg, side force cues (as indicated by aircraft roll attitude) were noticeably stronger in left sideslip than right sideslip. With dorsal ON and ring incidence at 6.5 deg the left and right side force cues were approximately equal.

Maneuvering Stability

9. Maneuvering stability characteristics were evaluated in ball-centered flight using symmetrical pull-ups and pushovers at conditions shown in table 1. Test results are shown in figures 8 and 9, appendix E. Maneuvering stability as indicated by variation of longitudinal control with normal acceleration was positive (increasing aft longitudinal control with increasing normal acceleration). A lateral-directional oscillation was excited during pull-up and pushover maneuvers with both 4.5 and 6.5 ring-fin angle of incidence. No attempt was made to control yaw and roll attitudes during these maneuvers. No problems were encountered in maintaining heading and roll attitude ±3 deg while performing nap-of-the-earth maneuvers. Additional testing should be conducted to determine if the phenomenon exists on an OH-58C helicopter with ring-fin tail rotor.

Dynamic Lateral-Directional Stability

10. The short-term dynamic lateral-directional stability characteristics were evaluated at 84 KCAS and 99 KCAS at the conditions

shown in table 1. Tests were conducted by applying left and right directional control pulses with cyclic and collective controls fixed. Left or right directional pedal control was displaced up to 1.0 in. for 0.5 second and then rapidly returned to the trim position. All flight controls were held fixed until aircraft motions were damped. Representative data are presented in figures 10 through 12, appendix E.

Dorsal Fin Installed:

11. Aircraft response after the directional control was returned to trim was heavily damped for both configurations with dorsal fin installed. Dorsal incidence appeared to have an insignificant effect on aircraft response. However, higher roll rates resulted from left directional control inputs for both configurations. This was substantiated during a qualitative evaluation in light turbulence during climbs, descents, and level flight at 30 KCAS to 103 KCAS. Lateral-directional oscillations of approximately ±5 deg yaw and ±3 deg roll were heavily damped and subsided in less than 3 sec or approximately 1 cycle with all flight controls fixed. Flight in light turbulence required small control inputs (±0.25 in. in each axis) to maintain heading ±3 deg and airspeed ±5 kts (HQRS 3).

Dorsal Fin Removed:

12. Removal of the dorsal fin with a ring incidence of 6.5 deg reduced directional stability. Aircraft response following a directional control pulse was moderately damped (fig. 12, app E). This was also qualitatively evaluated in light turbulence during climbs, descents, and level flight at 30 KCAS to 103 KCAS with dorsal fin removed and ring incidence of 6.5 deg. Lateral-directional oscillations of approximately ±5 deg yaw and ±3 deg roll were moderately damped and subsided in 5 to 10 sec or approximately 2 to 3 cycles with all controls fixed. Frequent moderate control inputs of ±0.75 in. directional control, ±0.5 in. lateral control, and ±0.5 in. longitudinal control were required to maintain heading ±3 deg and airspeed ±5 kts (HQRS 4).

Controllability

Hover:

13. Directional controllability was qualitatively evaluated during hovering flight at the conditions shown in table 1. Turn rates and elapsed time were estimated by the pilot and found to be essentially correct when compared with 16mm film documentation. Control positions were observed on cockpit gauges. Tests were

performed by applying directional control step inputs at a stabilized hover and arresting turns from a steady yaw rate. For all conditions tested, the aircraft responded in the proper direction with higher rates for increased directional control step inputs. Left and right hovering turns from steady yaw rates up to 40 deg/sec were easily arrested to within 5 deg of a desired heading in less than 2 sec. A minimum of 10% left directional control margin remained throughout the recovery from right hovering turns at 40 deg/sec yaw rate.

Forward Flight:

14. The directional control response (maximum angular rate per inch of control input) and control sensitivity (maximum angular acceleration per inch of control input) were evaluated in level flight at conditions shown in table 1. Tests were conducted by applying up to 1.0 in. left and right directional control step inputs with cyclic and collective controls fixed. Representative test results are presented in figures 13 and 14, appendix E. A comparision of control sensitivity and control response between the test aircraft and a 206A with standard vertical stabilizer (ref 4, app A) is shown in table 4. With a 6.5 deg ring incidence and dorsal fin removed, a 1.0 in. left directional control step input at 84 KCAS resulted in 85% tail rotor flapping immediately following the control input. The combination of ring-fin installation and hydraulically boosted directional controls resulted in a 50% increase in directional control sensitivity and reduction in time to maximum yaw rate in forward flight.

Low Speed Flight Characteristics

15. Low speed flight characteristics were evaluated at the conditions shown in table 1. Tests were conducted by flying relative azimuths (measured clockwise from the aircraft nose) of 105, 180, 210, 240 and 270 deg at a 5 ft skid height while stabilizing in formation with a ground pace vehicle. The task used to establish a handling qualities rating based on the HQRS was to maintain aircraft heading ±3 deg and skid height ±2 ft.

Right Sideward Flight:

16. Right sideward flight was evaluated on a relative wind azimuth of 105 deg. Data are presented in figure 15, appendix E. Aircraft heading was easily maintained ±3 deg with 0.25 in. directional control inputs (HQRS 3). Pitch attitude variation was less than ±2.0 deg and roll attitude variation was less than ±1.0 deg for all airspeeds tested. Directional control margin decreased to 10% at 27 knots true airspeed (KTAS).

Table 4. Directional Controllability

Tail Rotor Configuration	Airspeed (KCAS)	Control Response (deg/sec/in.)	Time to Max Rate (sec)	Control Sensitivity (deg/sec^2/in.)	Time to Max Accel (sec)
Standard 206A[1]	84	14	1.0	30	0.5
Ring Fin[2]	84	14	0.6	45 to 50	0.2

NOTES:

[1]Data obtained from reference 4, appendix A. Bell 206A helicopter equipped with standard vertical stabilizer. Directional flight controls are not hydraulically boosted.

[2]Ring incidence 4.5 deg and 6.5 deg with dorsal fin installed at 0.0 deg.

Rearward Flight:

17. Rearward flight was evaluated at relative wind azimuths of 180 and 210 deg. Data are presented in figures 16 and 17. Aircraft heading was maintained ± 3 deg with 0.25 to 0.50 in. directional control inputs approximately every 2 sec and longitudinal control inputs of 0.5 to 0.75 in. every 2 to 3 sec were required to maintain pitch attitude ± 2.0 deg (HQRS 4). The major difference between right sideward flight and rearward flight was an increase in longitudinal control inputs. Pilot workload was slightly higher along the 210 deg azimuth than the 180 deg azimuth.

Left Sideward Flight:

18. Left sideward flight was evaluated at relative wind azimuths of 240 and 270 deg. Data are presented in figures 18 and 19. Aircraft heading was maintained ± 3 deg with 0.25 to 0.5 in. directional control inputs every 1 to 2 sec and longitudinal control inputs of 0.5 to 0.75 in. were required every 2 to 3 sec to maintain pitch attitude ± 2.0 deg (HQRS 4). Pilot workload at both azimuths was essentially identical. Test results were compared to data obtained from an evaluation of the Bell 206A helicopter with standard tail rotor and vertical stabilizer assembly (ref 4, app A). The comparison revealed a significant reduction in yaw oscillations. The standard Bell 206A aircraft could not be stabilized directionally between 5 and 20 KTAS and ± 1.0 in. pedal inputs barely contained yaw oscillations within a 20 deg azimuth. The combination of hydraulically boosted directional controls and ring-fin assembly resulted in significantly improved low airspeed handling qualities in left sideward flight.

Simulated Engine Failures

19. Aircraft response to simulated sudden engine failure in forward flight was evaluated at conditions shown in table 1. Engine failure was simulated by rapidly rolling the throttle to flight idle. For ring incidences of 6.5 deg and 4.5 deg with dorsal fin installed all flight controls were held fixed for 2 sec resulting in a minimum transient main rotor speed of 230 rpm. No control delay was attempted with 6.5 deg ring incidence and dorsal removed due to the high tail rotor flapping (85%) observed during controllability tests (para 13). The high yaw and roll rates following the loss of power provided immediate cues to the pilot. The aircraft was easily returned to ball-centered flight with a mimimum of 20% right pedal control remaining during the recovery to stabilized autorotation and easily

maneuvered through 90 deg coordinated heading changes at airspeeds between 40 and 100 KCAS with a minimum of 20% right pedal control remaining. Installation of the ring-fin tail rotor does not adversely effect aircraft response to sudden engine failure.

CONCLUSIONS

GENERAL

20. The combination of hydraulically boosted directional control and ring fin assembly resulted in improved low airspeed handling qualities, particularly in left sideward flight, and approximately 50% increased directional control sensitivity in forward flight.

SPECIFIC

21. The following specific conclusions were reached relative to the Bell 206 helicopter equipped with a combination of hydraulically boosted directional flight controls and ring fin tail rotor assembly:

a. Yaw oscillations during left sideward flight are significantly reduced (para 18).

b. Adequate directional control margin (10% control remaining) was available to easily arrest hovering turns at 40 deg/sec steady yaw rate to within 5 deg of a desired heading within 2 sec (para 14).

c. Directional control sensitivity is increased by approximately 50% and time to maximum yaw rate is reduced in forward flight (para 13).

RECOMMENDATIONS

22. Testing should be conducted to determine the independent effects of hydraulically boosted directional controls and ring fin tail rotor assembly on the OH-58C helicopter (para 6).

23. Testing should be conducted to determine if the lateral-directional oscillation during pull-up and pushover maneuvers exists on the OH-58C helicopter with ring fin tail rotor (para 9).

APPENDIX A. REFERENCES

1. Letter, AVSCOM, DRDAV-DI, 23 May 1982, subject: Government Pilot Evaluation of the BHT 206B/Ring-Fin Tail Rotor, USAAEFA Project No 83-12. (Test Request)

2. Letter, ATL, SAVDL-ATL-CD, 23 November 1983, subject: Government Flight Release for Ring-Fin Tail Rotor System Program, Contract DAAK51-83-C-0025.

3. Naval Test Pilot School Flight Test Manual, Naval Air Test Center, USNTPS-FTM No. 101, *Helicopter Stability and Control,* June 1968.

4. Final Report, USAAVCOM Project No. 67-13, *Engineering Flight Test of the Light Observation Helicopter (LOH) Model 206A Armed (XM27E1) and Unarmed,* December 1967.

APPENDIX B. AIRCRAFT DESCRIPTION

GENERAL

1. The test aircraft (Commercial Registration Number N8560F) was a Model 206 helicopter manufactured by Bell Helicopter Textron, Fort Worth, Texas. The aircraft incorporated a nodal beam designed to reduce airframe vibrations and was modified to include a Ring-Fin Tail Rotor System. Effects of the nodal beam installation on this test are unknown. The aircraft had single two-bladed, semi-rigid, teetering type main and tail rotors. The Bell 206A tail rotor system (photo 1) was modified by replacing the standard vertical stabilizer with a ring shaped shroud, incorporating a dorsal fin, around the existing tail rotor (photos 2 through 5). The ring-fin incidence relative to the aircraft center line was ground adjustable and the dorsal could be removed or set at zero degrees relative to the ring-fin center line. The dimension of the dorsal fin is shown in figure 1. The directional flight controls were hydraulically boosted and did not include a force gradient or trim feel system. The test aircraft was powered by a turbo-shaft engine designated as a Model 250-C20 manufactured by the Allison Divison of General Motors Corporation. The engine had an uninstalled intermediate power rating of 400 shaft horsepower (shp) at sea level standard day conditions. The main transmission was limited to 270 shp continuous operation and 317 shp for 5 minutes. Aircraft maximum gross weight was 3200 lb. The fuel capacity was 509 lb (JP-5).

2. Basic helicopter design data are listed below:

Main Rotor

Diameter	33.3 ft
Disk area	871 sq ft
Blade chord	13 in.
Rotor solidity	0.0414
Blade twist	-10°
Hub pre-cone	2-1/4°
Tip speed @ 100%	687 fps
RPM normal @ 100%	394
Rotor inertia	584 slug-ft^2

Tail Rotor

Diameter	5.17 ft
Chord	5.25 in.
Solidity	0.107745
Tip speed @ 100%	690 fps
RPM @ 100%	2550 RPM
Pre-cone	0

Photo 1. Bell 206A Helicopter With Standard Tail Rotor System

Photo 2. Bell Model 206 With Ring Fin Tail Rotor (Side View)

Photo 3. Ring Fin Assembly (Right Side View)

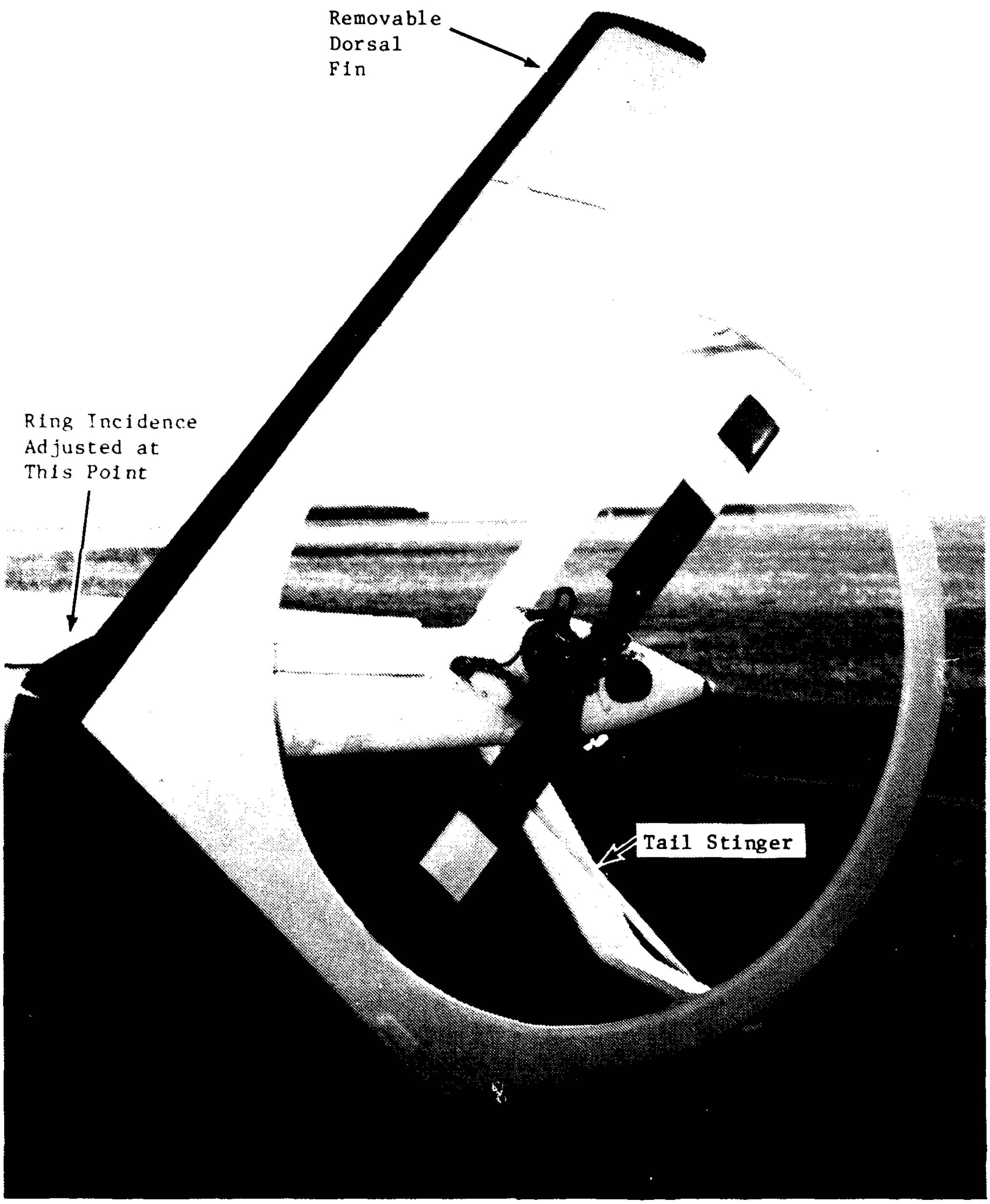


Photo 4. Ring Fin Assembly (Left Side View)

Photo 5. Ring Fin Assembly (Rear View)

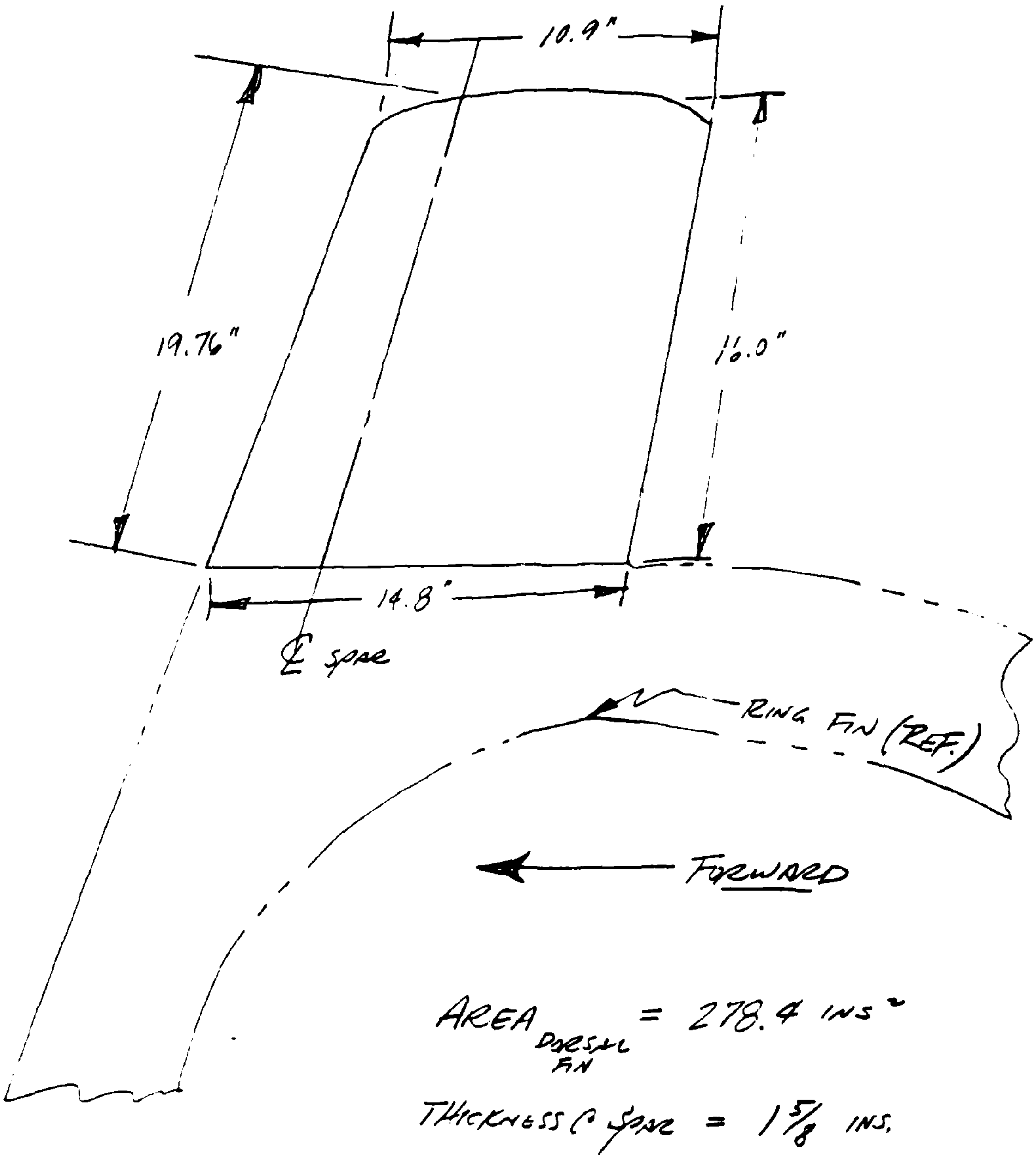


Figure 1. Dorsal Fin Dimensions

Main Transimission

T.O. power rating (5 min)	317 shp
Maximum continuous rating	270 shp
Engine to main rotor ratio	15.228:1
Engine to tail rotor drive shaft ratio	2.353:1
Tail Rotor Gearbox Ratio	1:1

Power Plant

Designation: Allision 250-C20	
Intermediate power rating (sea level standard day)	400 shp

APPENDIX C. INSTRUMENTATION

1. Test instrumentation was installed, calibrated, and maintained by Bell Helicopter Textron, Inc. (BHTI). Data was displayed in the cockpit and recorded on magnetic tape onboard the aircraft.

2. A test boom extending forward from the nose of the aircraft was installed and incorporated an angle of sideslip and angle of attack sensors and a pitot-static airspeed sensor.

3. Parameters measured during this test were:

<u>Pilot Panel</u>

Airspeed (boom)
Altitude (boom)
Angle of sideslip
Rotor speed
Center of gravity normal acceleration
Free air temperature
Fuel used*
Engine torque
Tail rotor torque
Control Position
    Longitudinal
    Lateral
    Directional
    Collective
Instrumentation Controls
Run Number

<u>Magnetic Tape Recorder</u>

Control Position
    Longitudinal
    Lateral
    Directional
Aircraft attitude
    Pitch
    Roll
    Yaw
Aircraft angular velocity
    Pitch
    Roll
    yaw
Center of gravity normal acceleration
Tail rotor flapping
Tail rotor torque
Event marker
Run number

*Standard aircraft instrument

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

HANDLING QUALITIES

Control Positions in Trimmed Forward Flight

1. Control positions as a function of airspeed were determined during stabilized level flight.

Static Lateral-Directional Stability

2. These tests were conducted by establishing the trim condition and then varying sideslip angle incrementally up to the preestablished limits. During each test, collective control position and airspeed were held constant and altitude allowed to vary as required.

Maneuvering Stability

3. Pull-up and pushover maneuvers were used to evaluate the maneuvering stability. This test was accomplished by establishing the trim condition and then incrementally increasing and decreasing load factor by increasing and decreasing pitch attitude while holding collective control position constant.

Dynamic Stability

4. Dynamic lateral-directional stability was evaluated to determine the short-period characteristics. Tests were conducted by applying left and right directional control pulses with cyclic and collective controls fixed. Left or right directional pedal control was displaced up to 1.0 in. for 0.5 sec and then rapidly returned to the trim position. All flight controls were held fixed until aircraft motions were damped. Test results were substantiated through qualitative evaluation during flight in light turbulence.

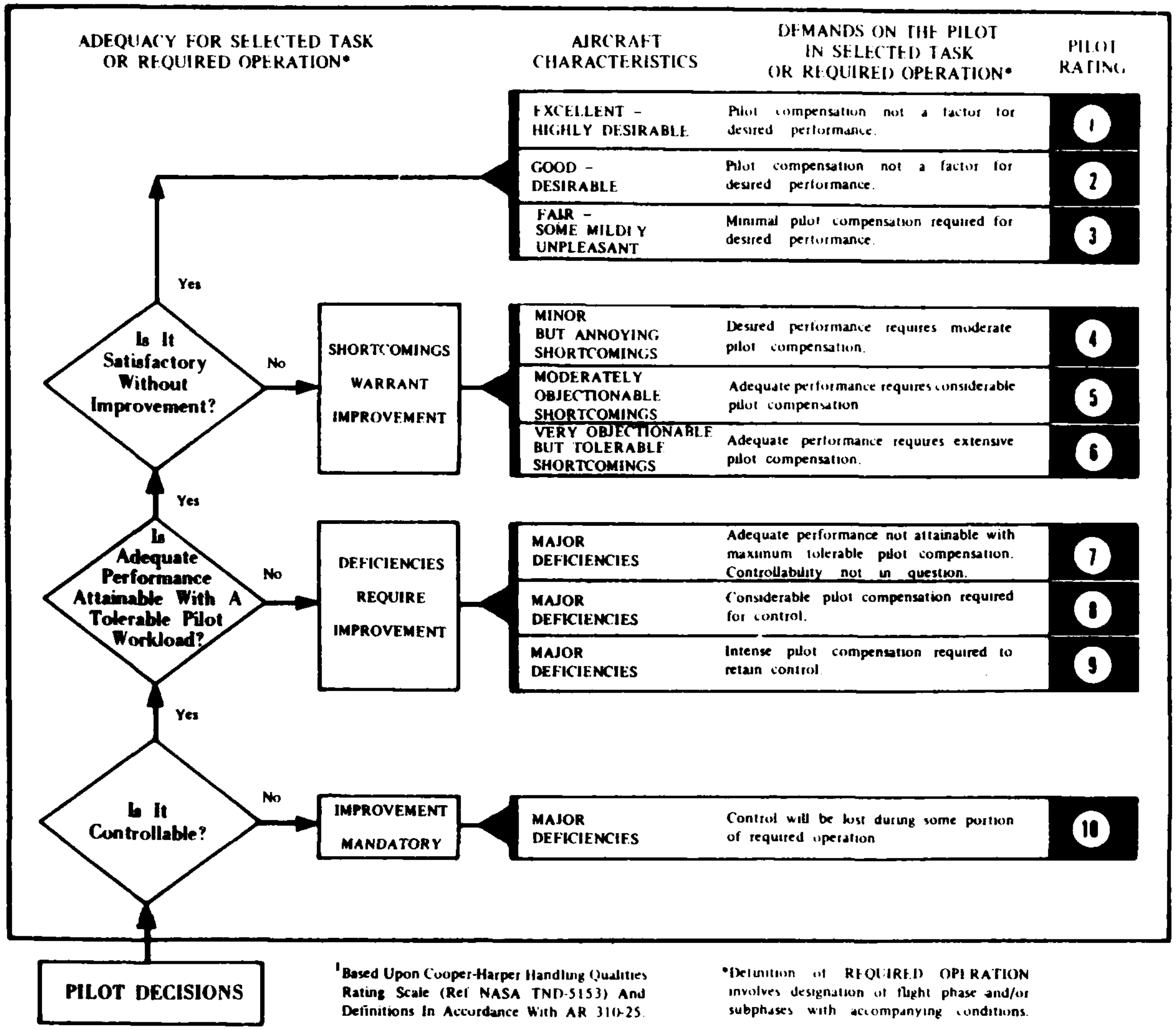
Controllability

5. Controllability testing was conducted by first establishing a trim condition and then making a step-type control input which was held until the aircraft had reached a maximum rate. Directional control inputs of varying size were made in each direction. Directional controllability at a hover was qualitatively evaluated by performing turn arrestments from steady rate hovering turns up to 40 deg/sec.

DEFINITIONS

Qualitative Rating Scales

6. A Handling Qualities Rating Scale was used to augment pilot comments and is presented as figure 1.



[1]Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) And Definitions In Accordance With AR 310-25.

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions.

Figure 1. Handling Qualities Rating Scale

APPENDIX E. TEST DATA

INDEX

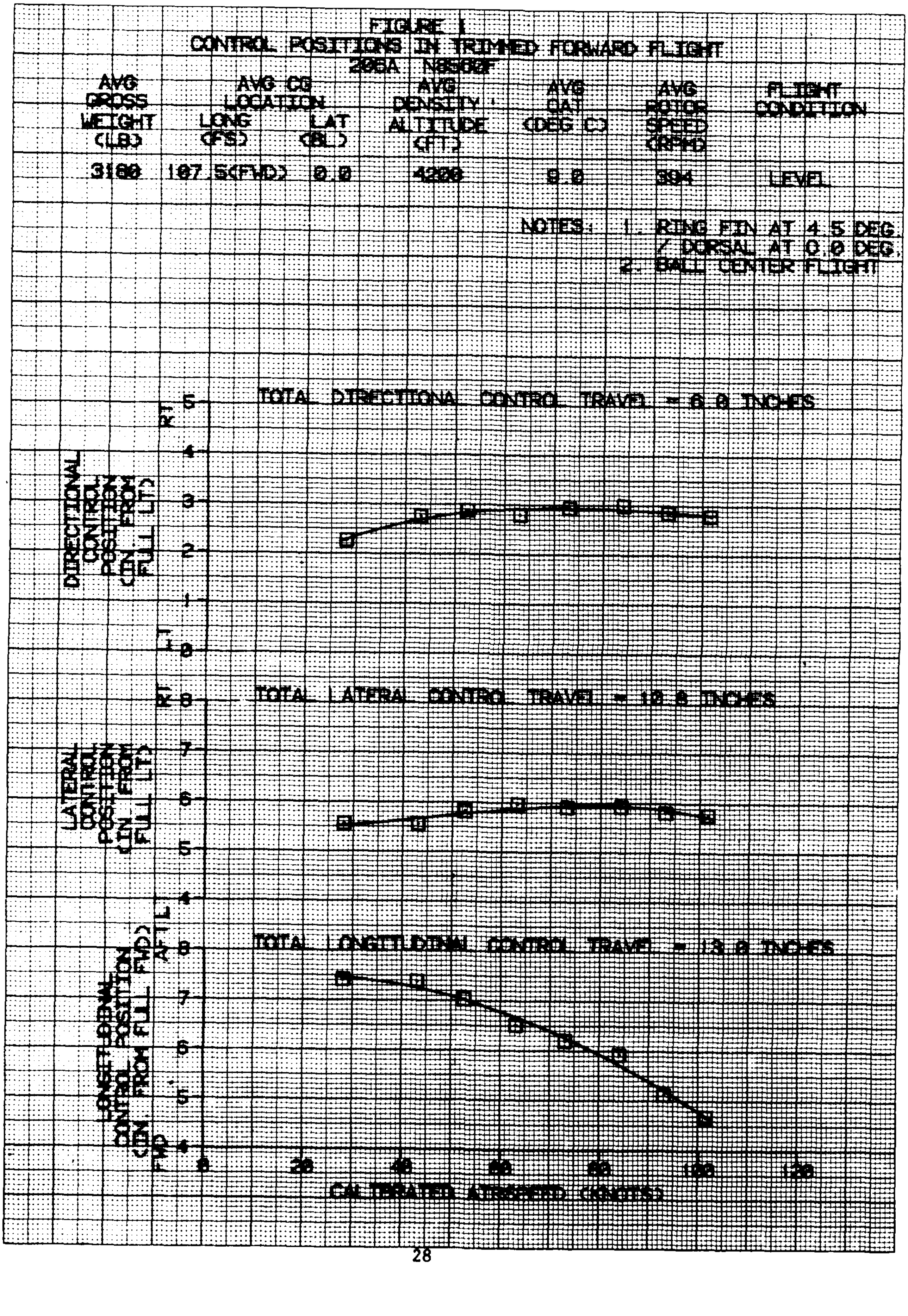


FIGURE 1
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
206A N8560F
AVG GROSS WEIGHT (LB)
AVG CG LOCATION
LONG (FS)
LAT (BL)
AVG DENSITY ALTITUDE (FT)
AVG OAT (DEG C)
AVG ROTOR SPEED (RPM)
FLIGHT CONDITION
3180
107.5(FWD)
0.0
4200
9.0
394
LEVEL
NOTES: 1. RING FIN AT 4.5 DEG.
/ DORSAL AT 0.0 DEG.
2. BALL CENTER FLIGHT
TOTAL DIRECTIONAL CONTROL TRAVEL = 6.0 INCHES
DIRECTIONAL CONTROL POSITION (IN FROM FULL LT)
RT
LT
TOTAL LATERAL CONTROL TRAVEL = 10.0 INCHES
LATERAL CONTROL POSITION (IN FROM FULL LT)
RT
LT
TOTAL LONGITUDINAL CONTROL TRAVEL = 13.0 INCHES
LONGITUDINAL CONTROL POSITION (IN FROM FULL FWD)
AFT
FWD
0
20
40
60
80
100
120
CALIBRATED AIRSPEED (KNOTS)

FIGURE 2
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
206A N8560F

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
3130	111.0(AFT)	0.0	3400	2.0	394	LEVEL

NOTES: 1. RING FIN AT 4.5 DEG / DORSAL AT 0.0 DEG
2. BALL CENTER FLIGHT

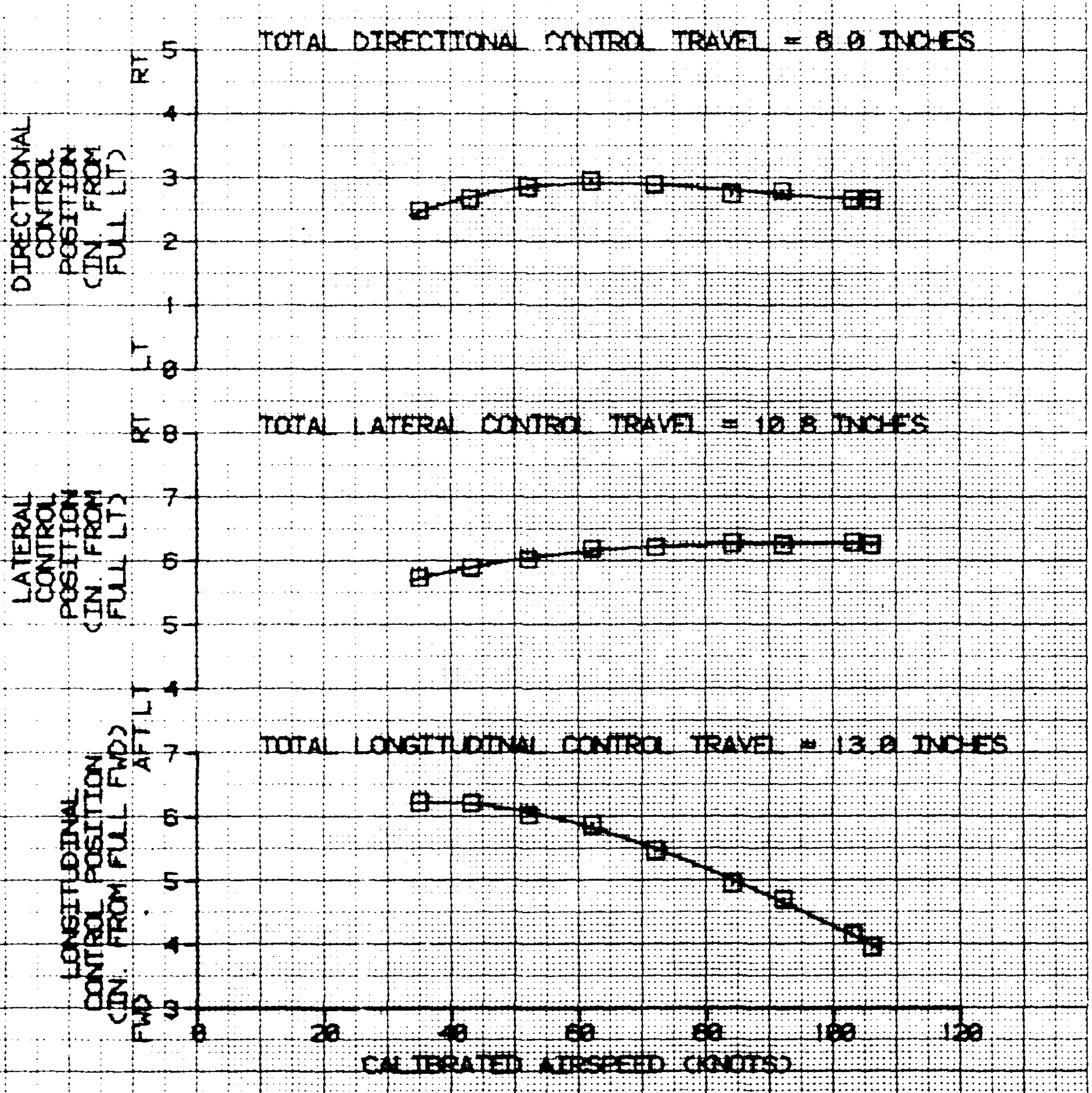


FIGURE 8
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
206A N8560F

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
3180	111.0(AFT)	0.0	3400	2.0	394	LEVEL

NOTES: 1. RING FIN AT 6.5 DEG / DORSAL AT 0.0 DEG
2. BALL CENTER FLIGHT

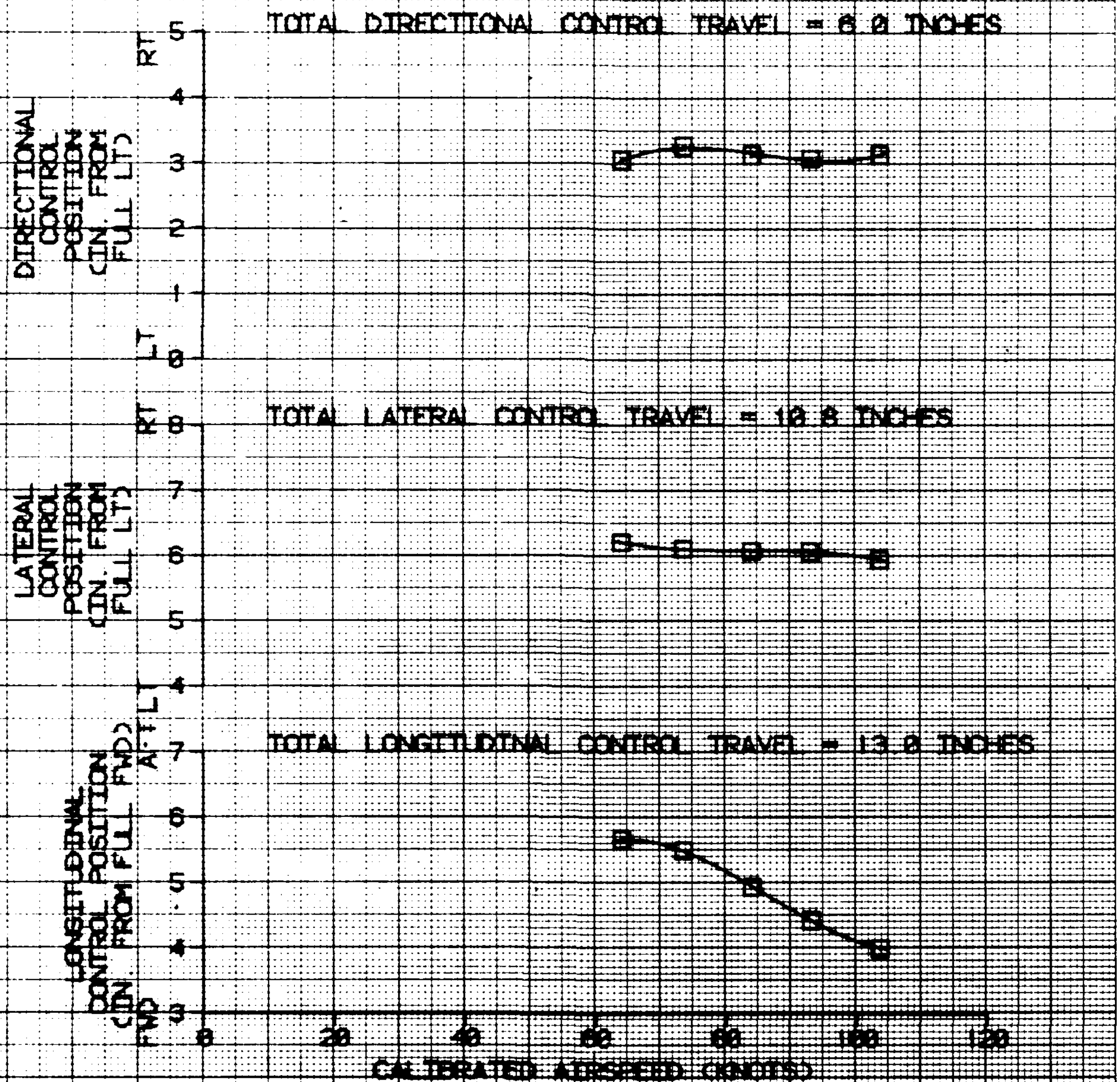


FIGURE [illegible]

CONTROL POSITIONS IN [illegible] FLIGHT

206A N85[illegible]

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	[illegible] (DEG [illegible])	[illegible] ROTOR SPEED (RPM)	FLIGHT CONDITION
3170	111.0(AFT)	0.0	2900	[illegible]	[illegible]	LEVEL

NOTES: 1. [illegible] 6.5 DEG. / DORSAL OFF
2. BALL CENTER FLIGHT

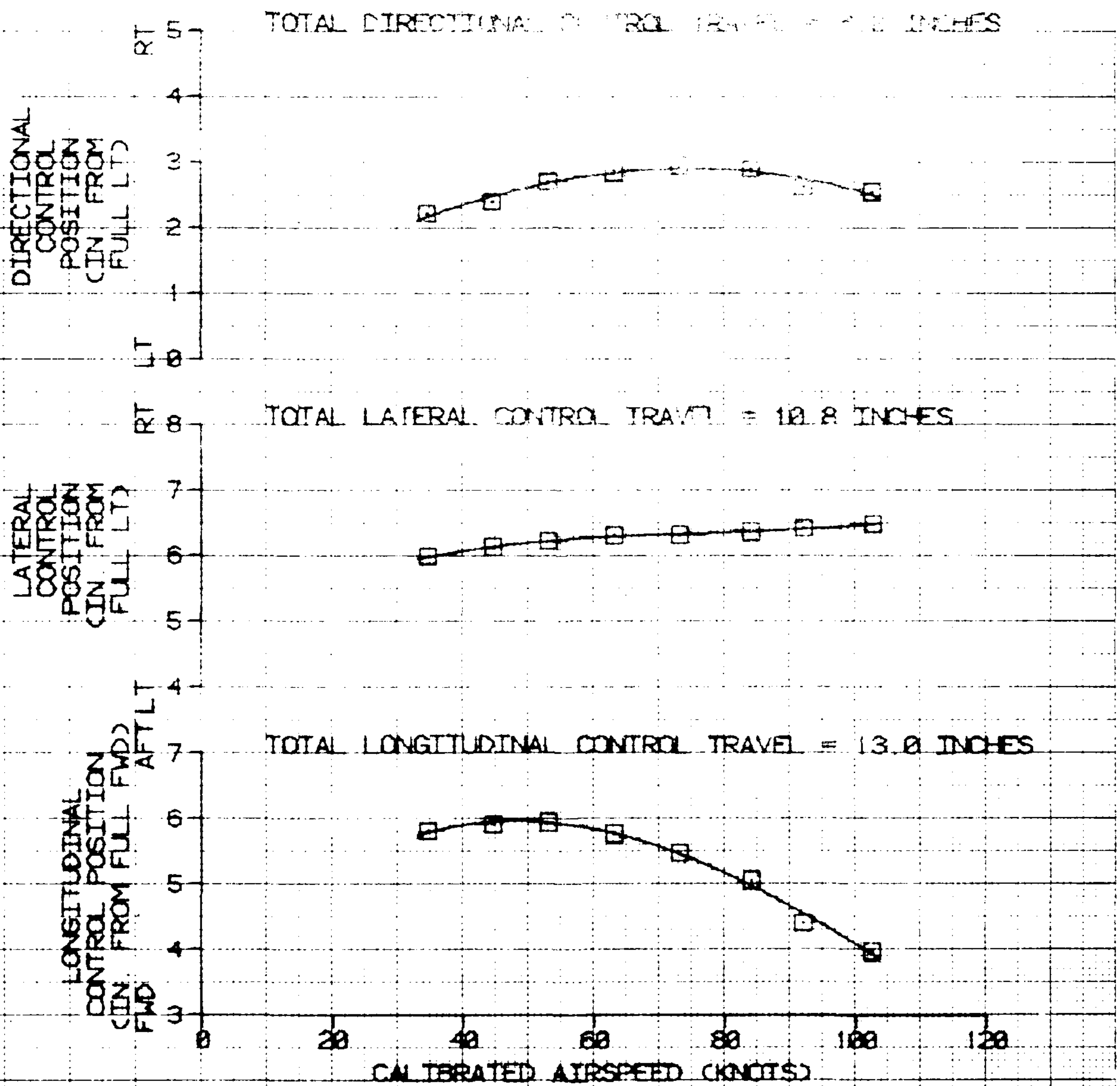


FIGURE 5
STATIC LATERAL-DIRECTIONAL STABILITY
206A N8560F

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CALIBRATED AIRSPEED (KTS)
3080	111.3(AFT)	0.0	4360	10.0	394	84

NOTES 1. LEVEL FLIGHT
2. SHADED SYMBOLS DENOTE TRIM
3. RING FIN AT 4.5 DEG.
/ DORSAL AT 0.0 DEG.

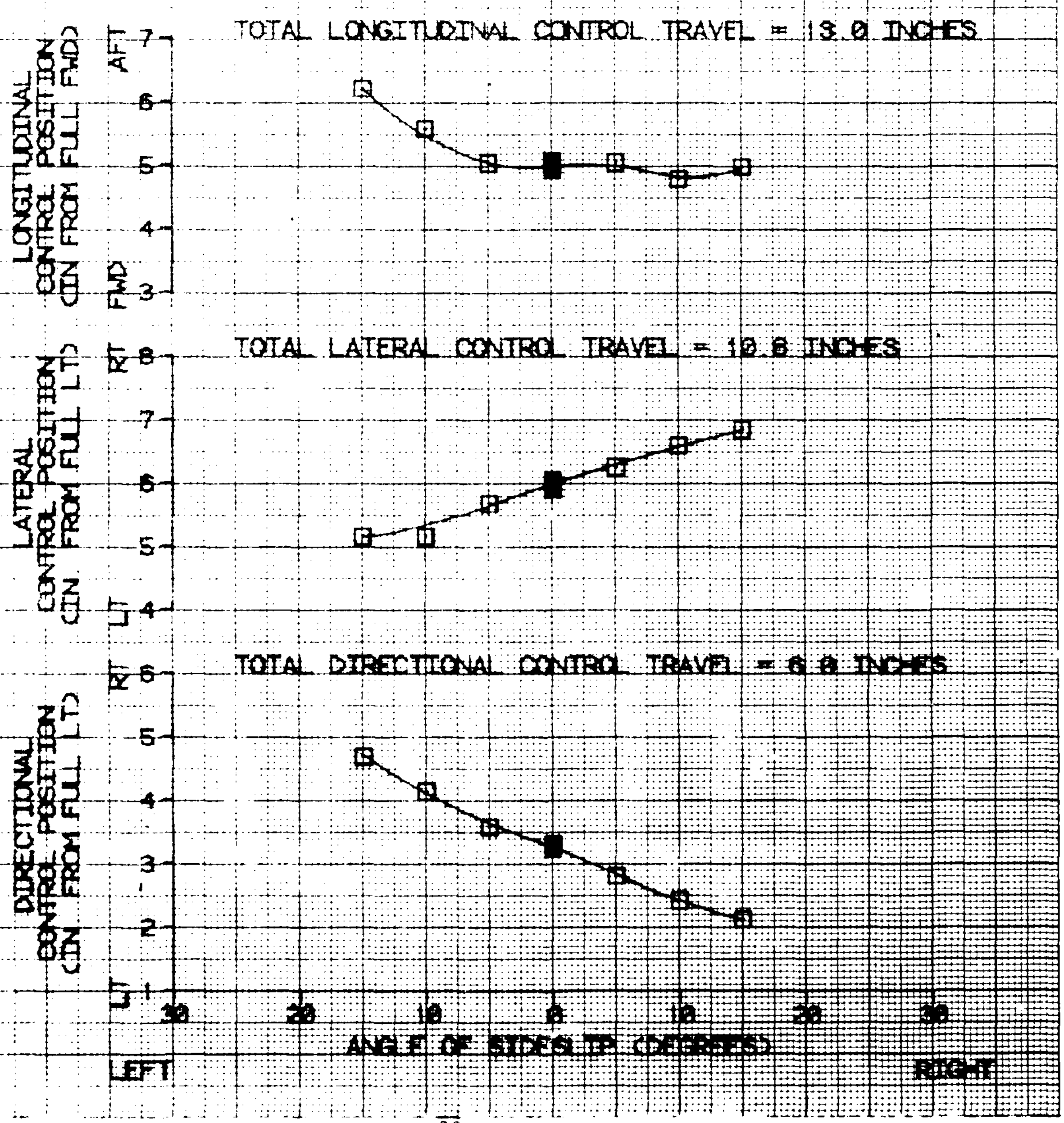


FIGURE 5
STATIC LATERAL-DIRECTIONAL STABILITY
206A N8560F

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CALIBRATED AIRSPEED (KTS)
3140	111.0(AFT)	0.0	3400	2.0	[illegible]	84

NOTES: 1. LEVEL FLIGHT
2. SHADED SYMBOLS DENOTE TRIM
3. RING FIN AT 6.5 DEG
/ DORSAL AT 0.0 DEG

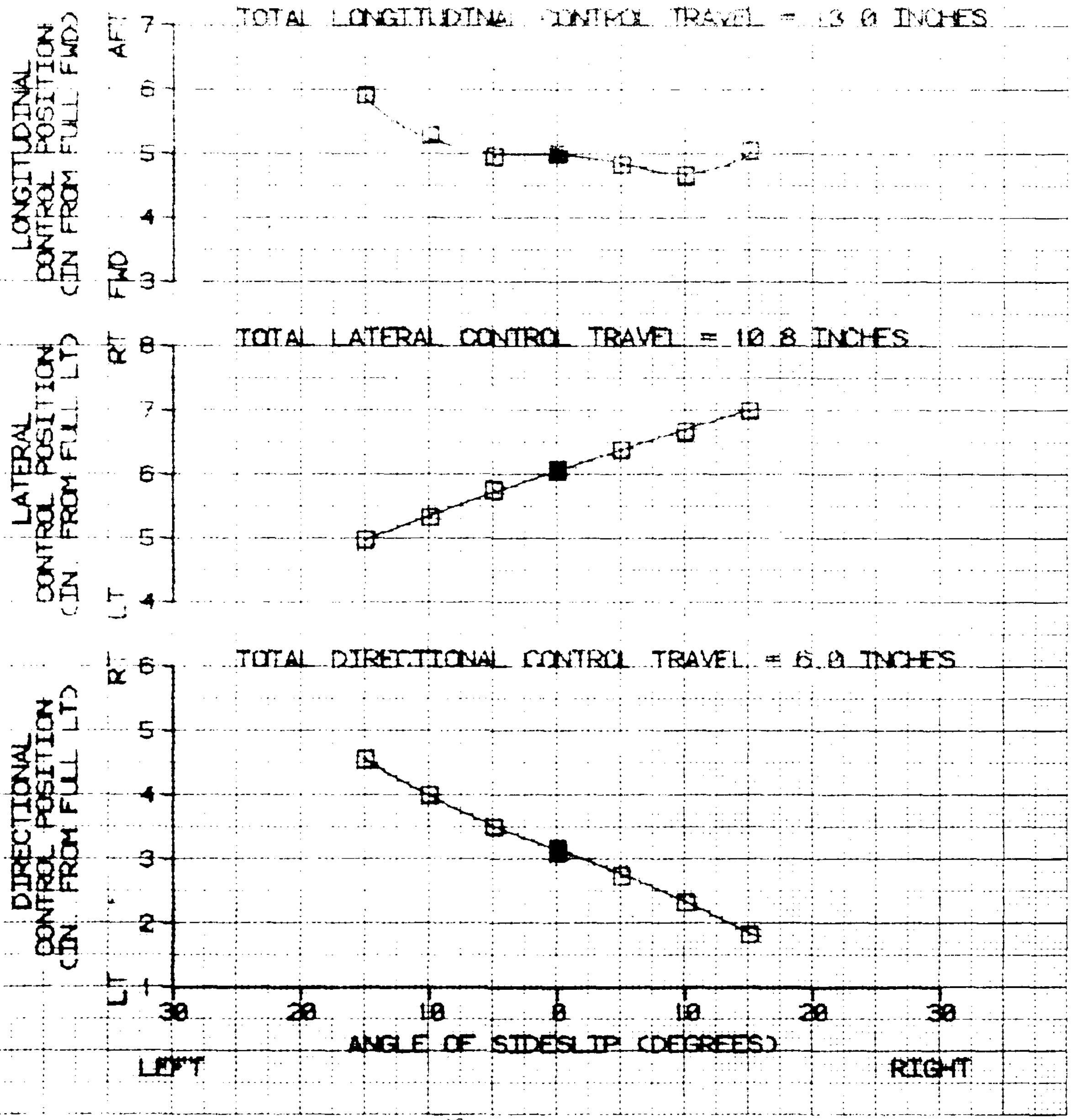


FIGURE 7
STATIC LATERAL-DIRECTIONAL STABILITY
206A N8560F

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG CALIBRATED AIRSPEED (KTS)
3160	111.0(AFT)	0.0	3030	-4.0	394	84

NOTES: 1. LEVEL FLIGHT
2. SHADED SYMBOLS DENOTE TRIM
3. RING FIN AT 6.5 DEG./ DORSAL OFF

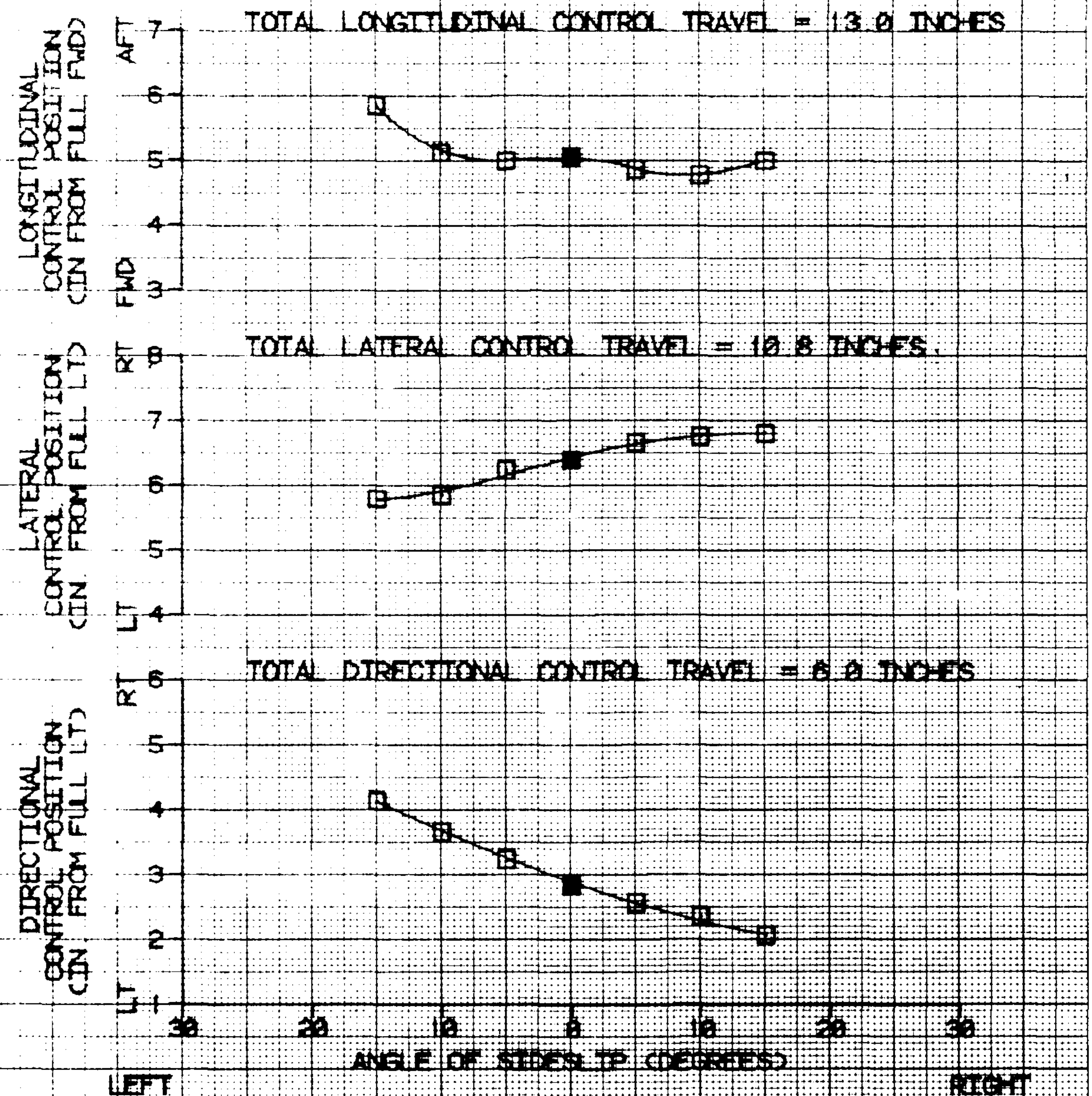


FIGURE 8
SYMMETRICAL PULL-UP MANEUVER
206A N8560F

GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION
3130	111.0 (AFT)	3000	10.0	394	84	WING LEVEL

NOTE: RING FIN AT 4.5 DEG./DORSAL AT 0.0 DEG.

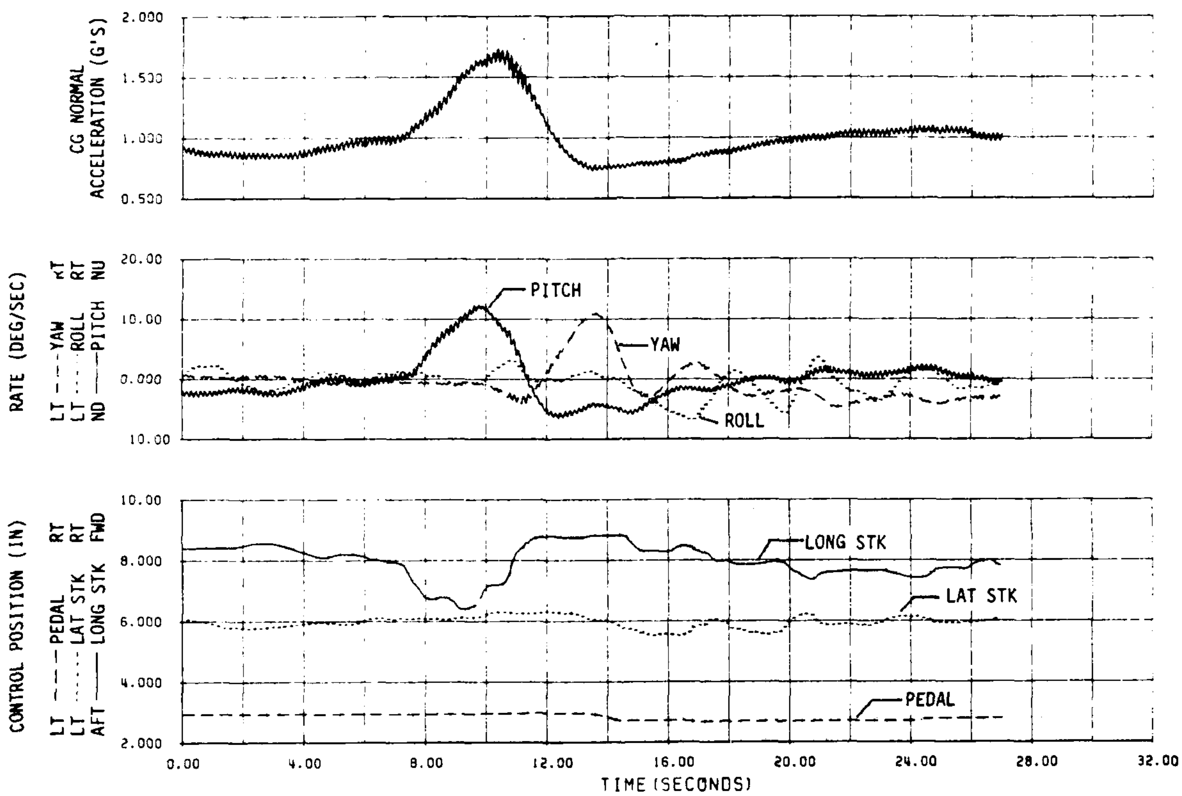


FIGURE 9
SYMMETRICAL PUSH-OVER MANEUVER
206A N8560F

GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION
3120	111.0 (AFT)	3000	10.0	394	84	WING LEVEL

NOTE: RING FIN AT 4.5 DEG./DORSAL AT 0.0 DEG.

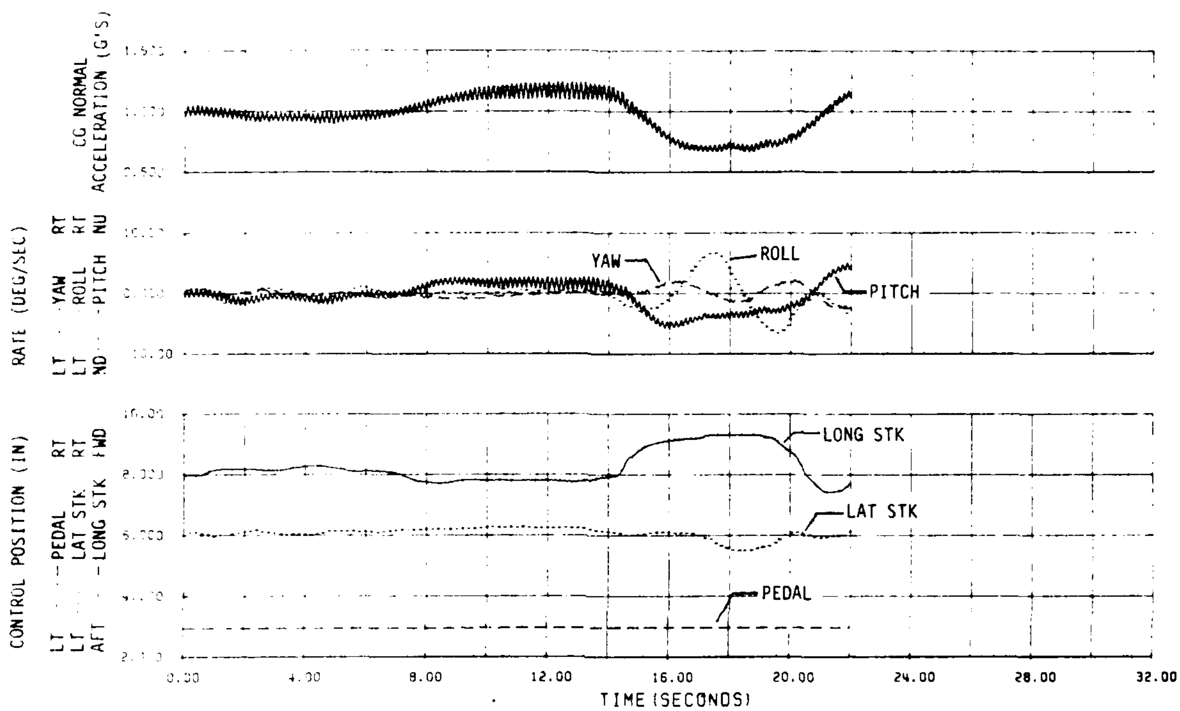


FIGURE 10
LEFT DIRECTIONAL PULSE
206A N8560F

GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION
3140	111.0 (AFT)	4400	10.0	394	99	LEVEL

NOTE: RING FIN AT 4.5 DEG./DORSAL AT 0.0 DEG.

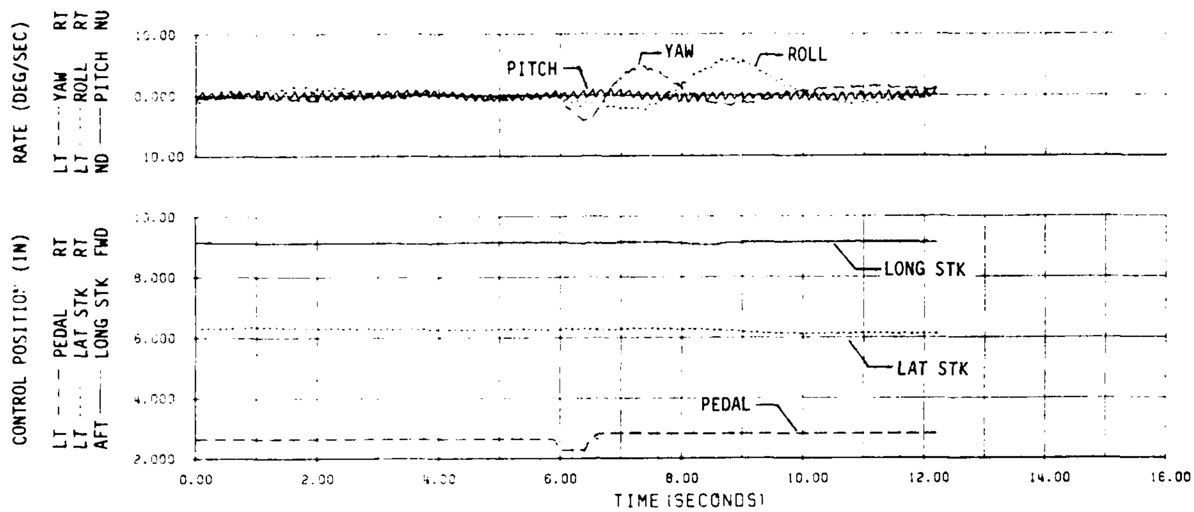


FIGURE 11
RIGHT DIRECTIONAL PULSE
206A N8560F

GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION
3090	111.0 (AFT)	3700	2.0	394	104	LEVEL

NOTE: RING FIN AT 6.5 DEG./DORSAL AT 0.0 DEG.

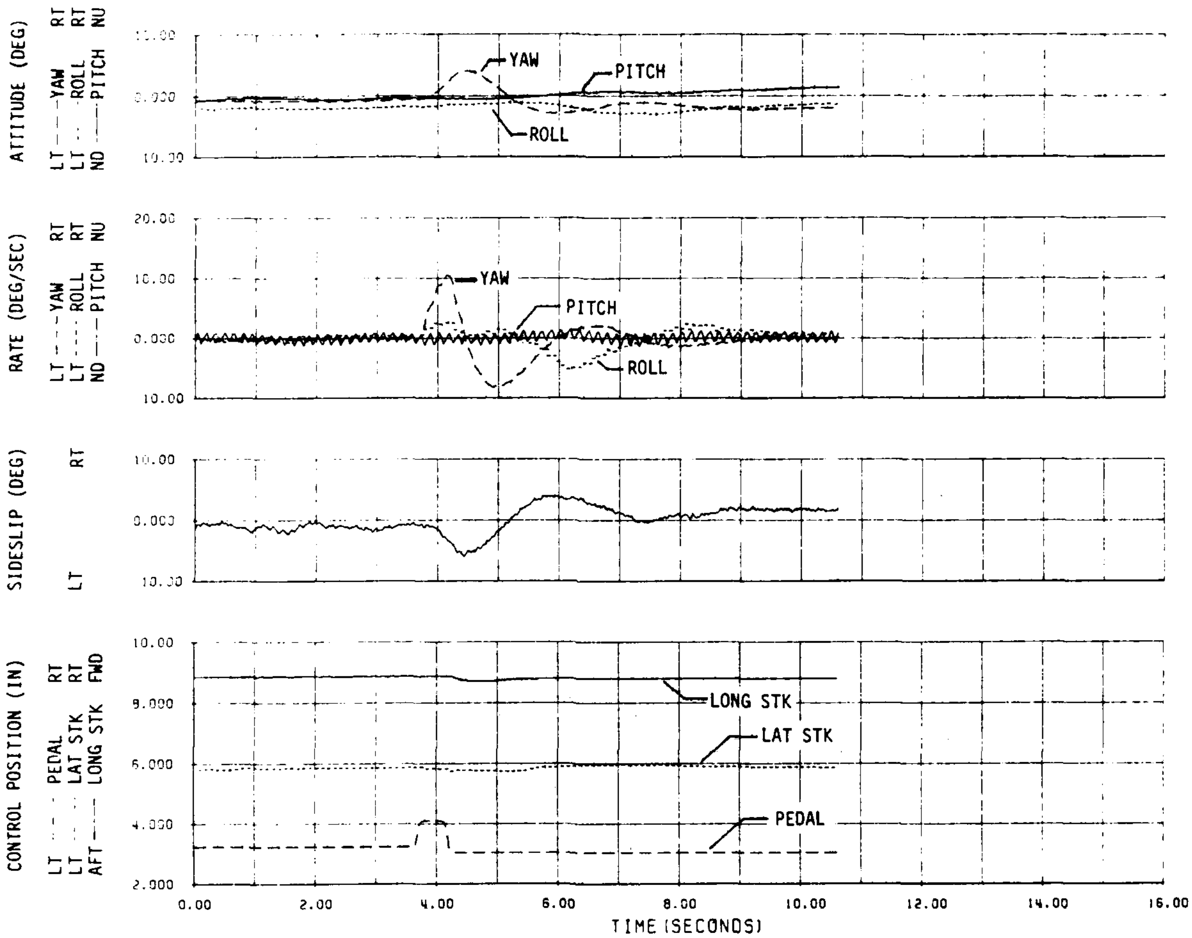


FIGURE 12
RIGHT DIRECTIONAL PULSE
206A N8560F

GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION
3100	111.0 (FWD)	2900	-4.0	394	84	LEVEL

NOTE: RING FIN AT 6.5 DEG./DORSAL OFF

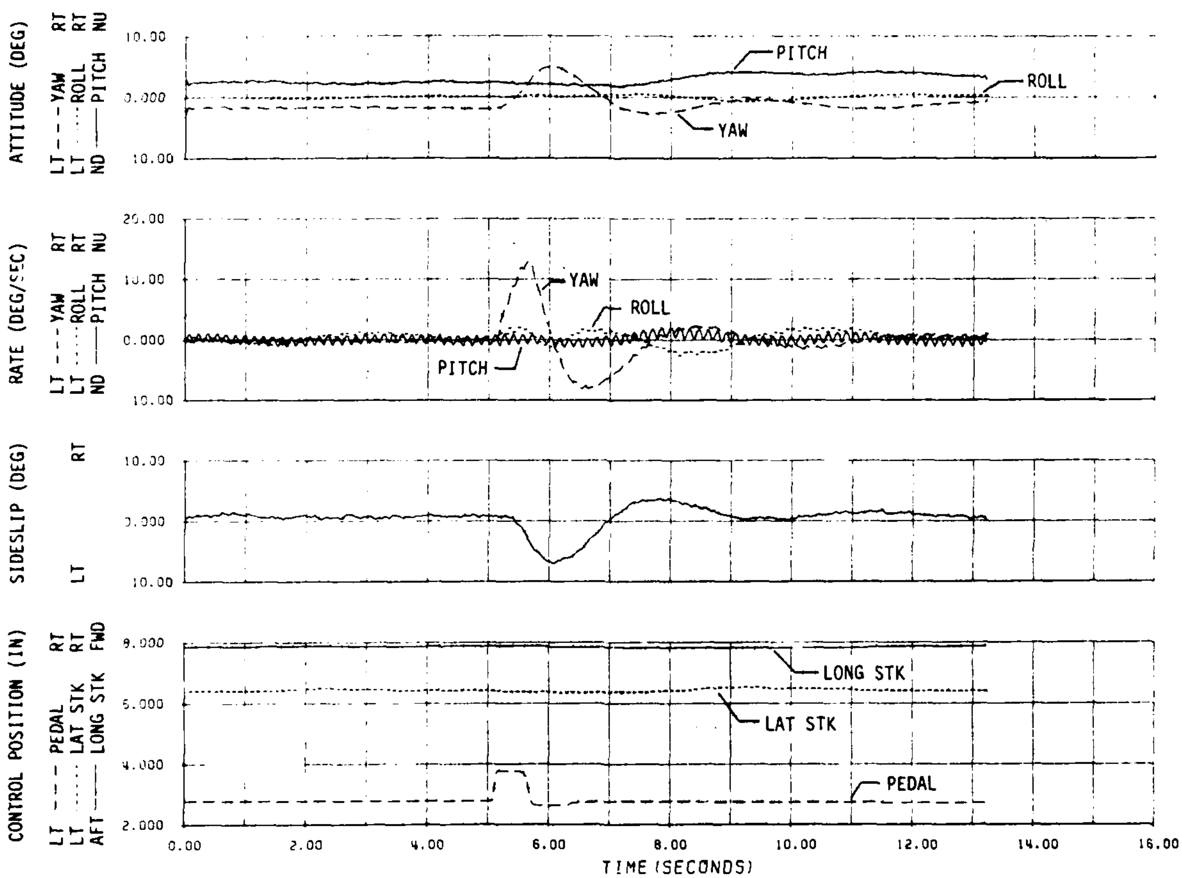


FIGURE 13
LEFT DIRECTIONAL STEP
206A N8560F

GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION
3110	111.0 (AFT)	3700	2.0	394	84	LEVEL

NOTE: RING FIN AT 6.5 DEG./DORSAL AT 0.0 DEG.

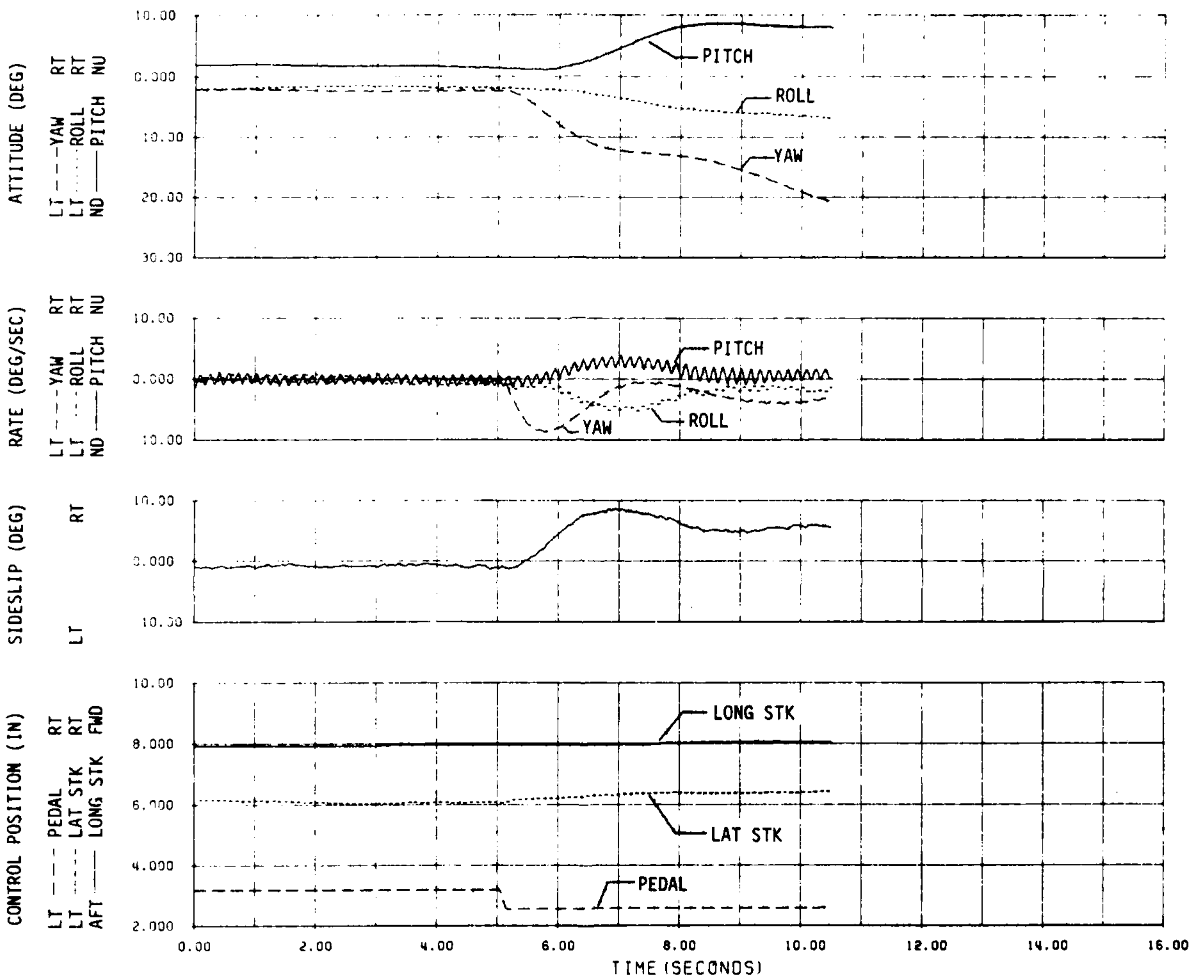


FIGURE 14
RIGHT DIRECTIONAL STEP
206A N8560F

GROSS WEIGHT (LB)	LONGITUDINAL CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	TRIM FLIGHT CONDITION
3120	111.0 (AFT)	3700	2.0	394	84	LEVEL

NOTE: RING FIN AT 6.5 DEG./DORSAL AT 0.0 DEG.

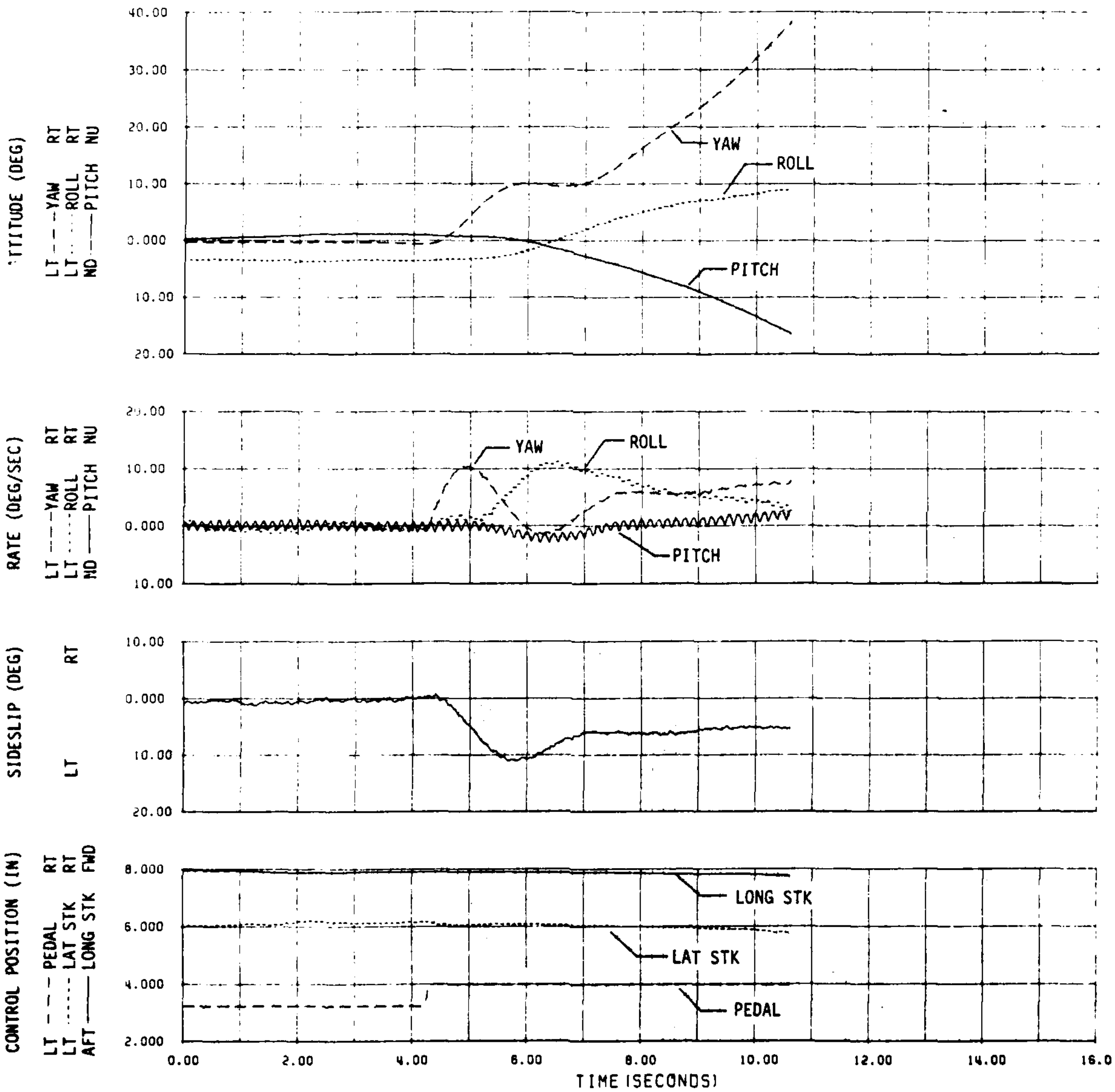


FIGURE 15
LOW SPEED FLIGHT 105 DEG. AZIMUTH
206A N8500F

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)
3150	111.0(AFT)	0.0	140	11.0	394	5

NOTES: 1. I DENOTES MAXIMUM CONTROL EXCURSION
2. RING FIN AT 6.5 DEG
/ DORSAL AT 0.0 DEG

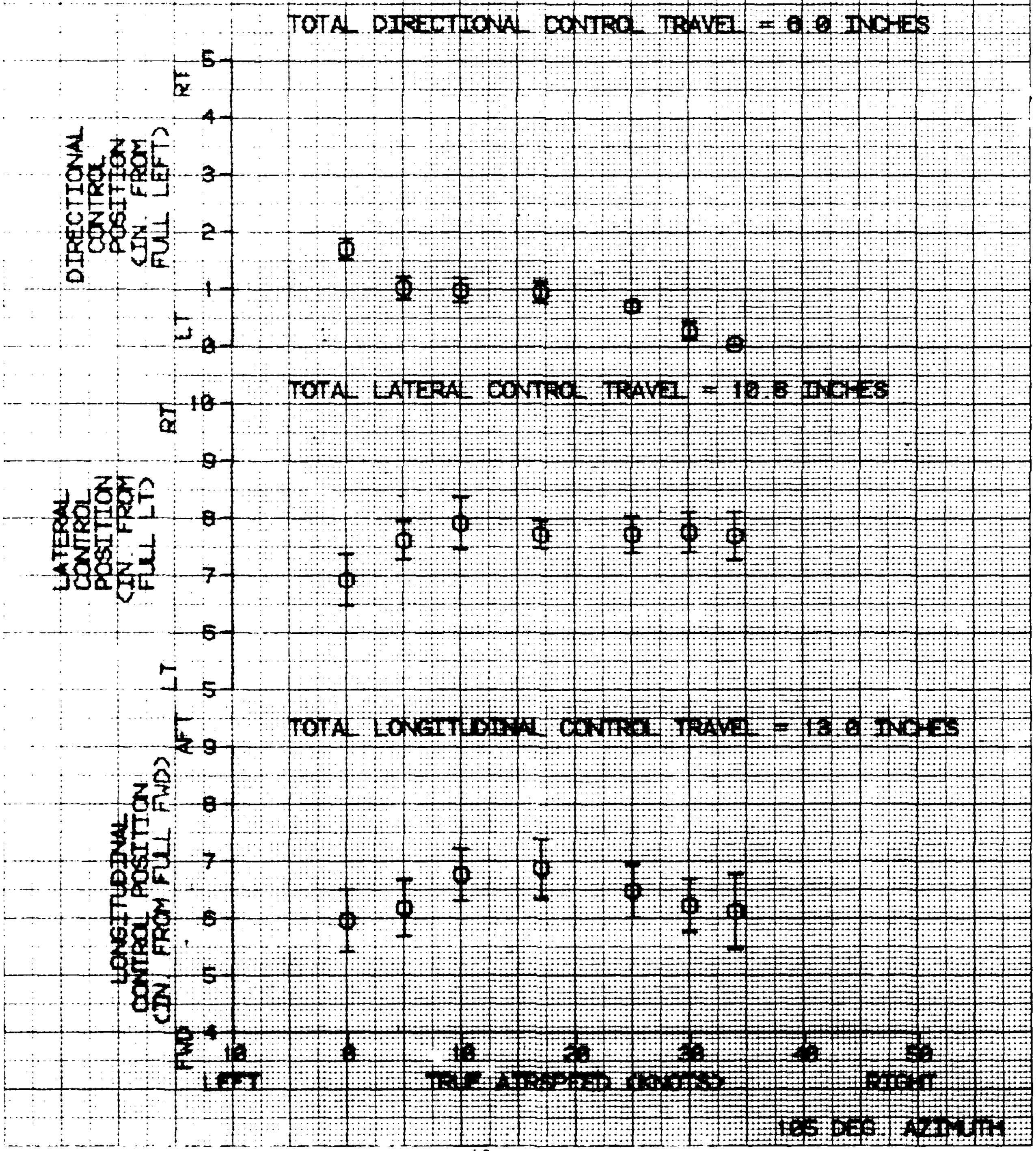


FIGURE 16
LOW SPEED FLIGHT 180 DEG. AZIMUTH
206A N8560F

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)
3100	111.0(AFT)	0.0	SEA LEVEL	10.0	394	5

NOTES: 1. I DENOTES MAXIMUM CONTROL EXCURSION
2. RING FIN AT 6.5 DEG.
/ DORSAL AT 0.0 DEG.

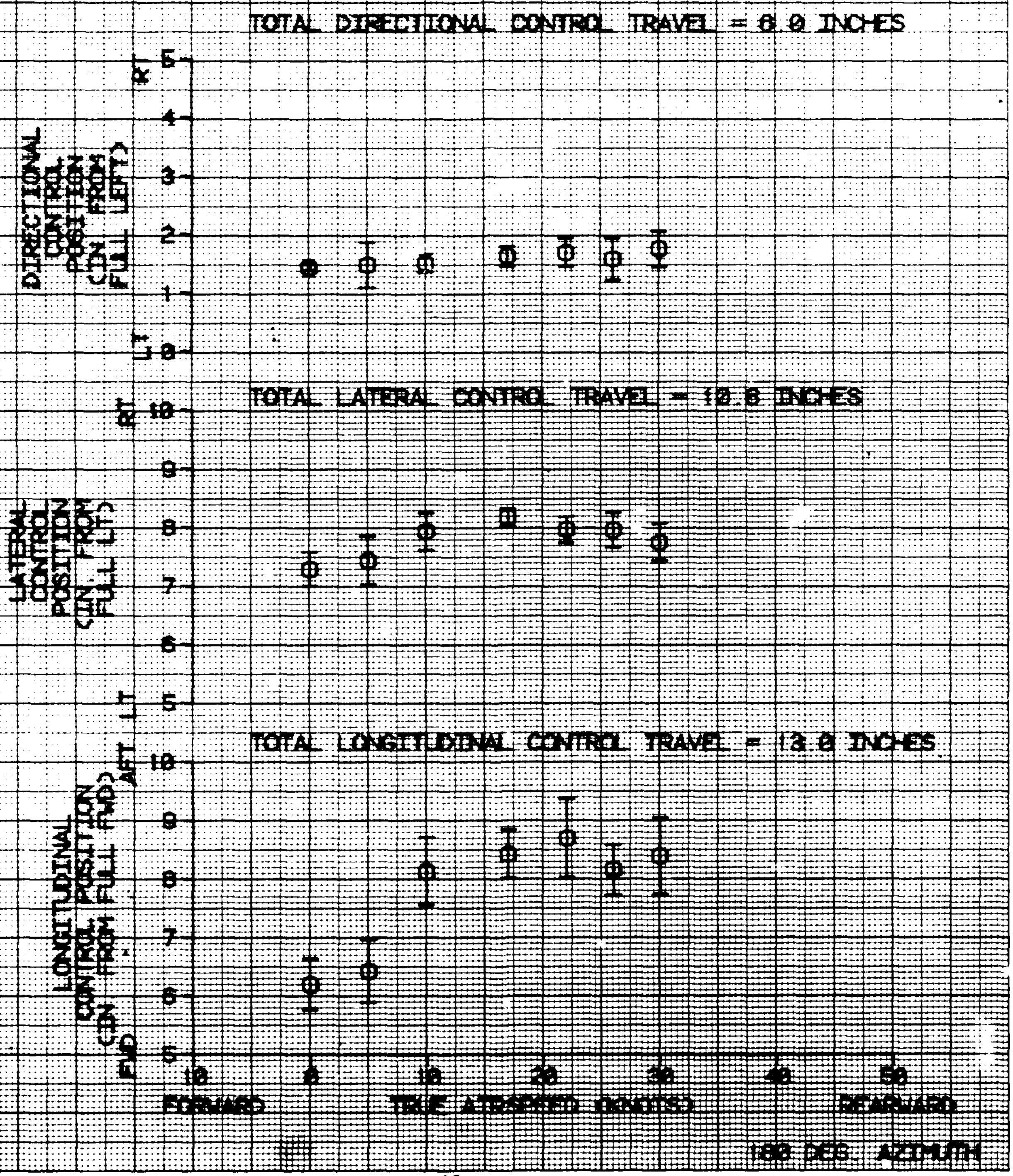


FIGURE 17
LOW SPEED FLIGHT 210 DEG. AZIMUTH
206A N8560F

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)
3170	111.0(AFT)	0.0	-250	8.0	394	5

NOTES: 1. I DENOTES MAXIMUM CONTROL EXCURSION
2. RING FIN AT 6.5 DEG.
/ DORSAL AT 0.0 DEG.

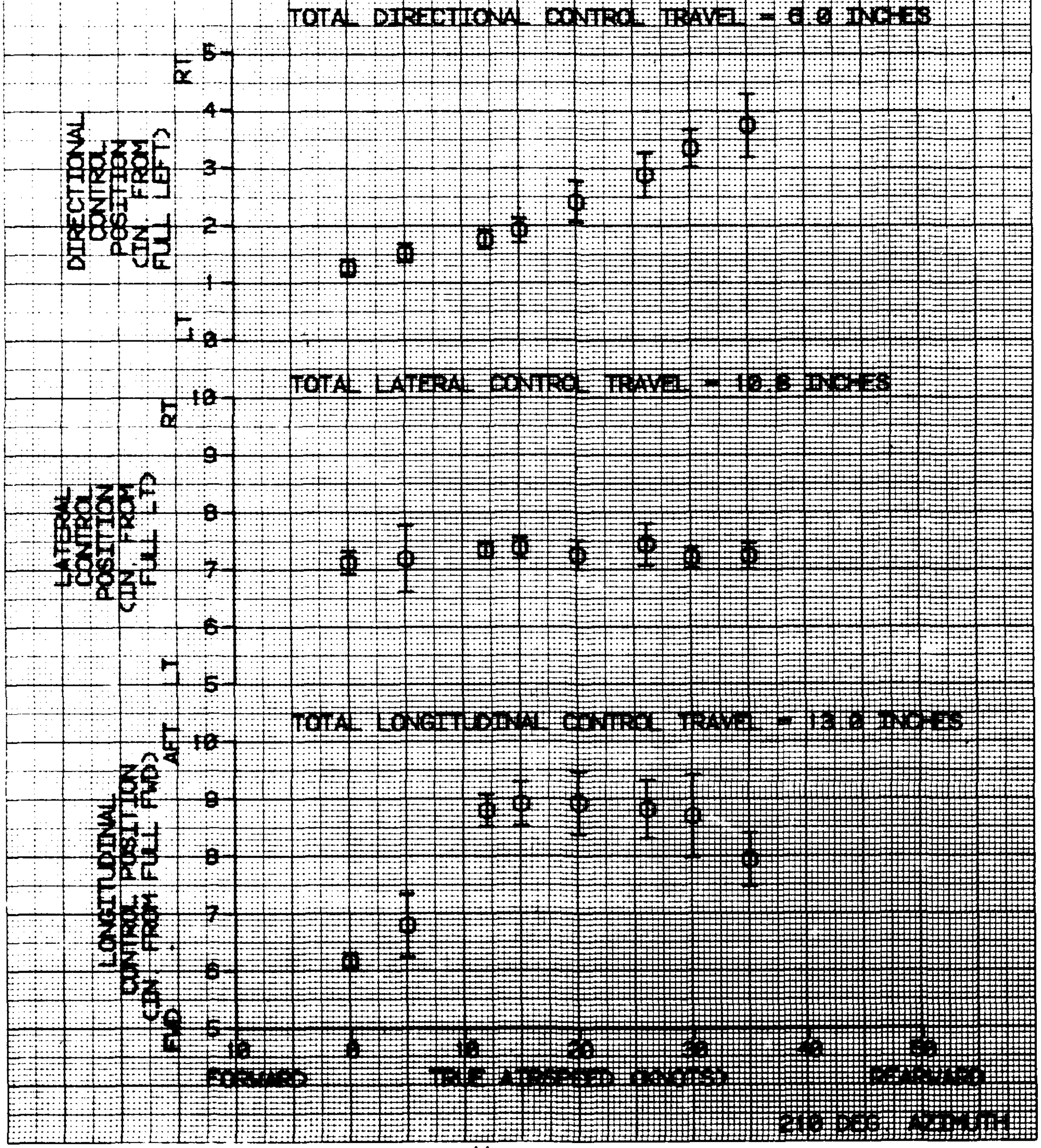
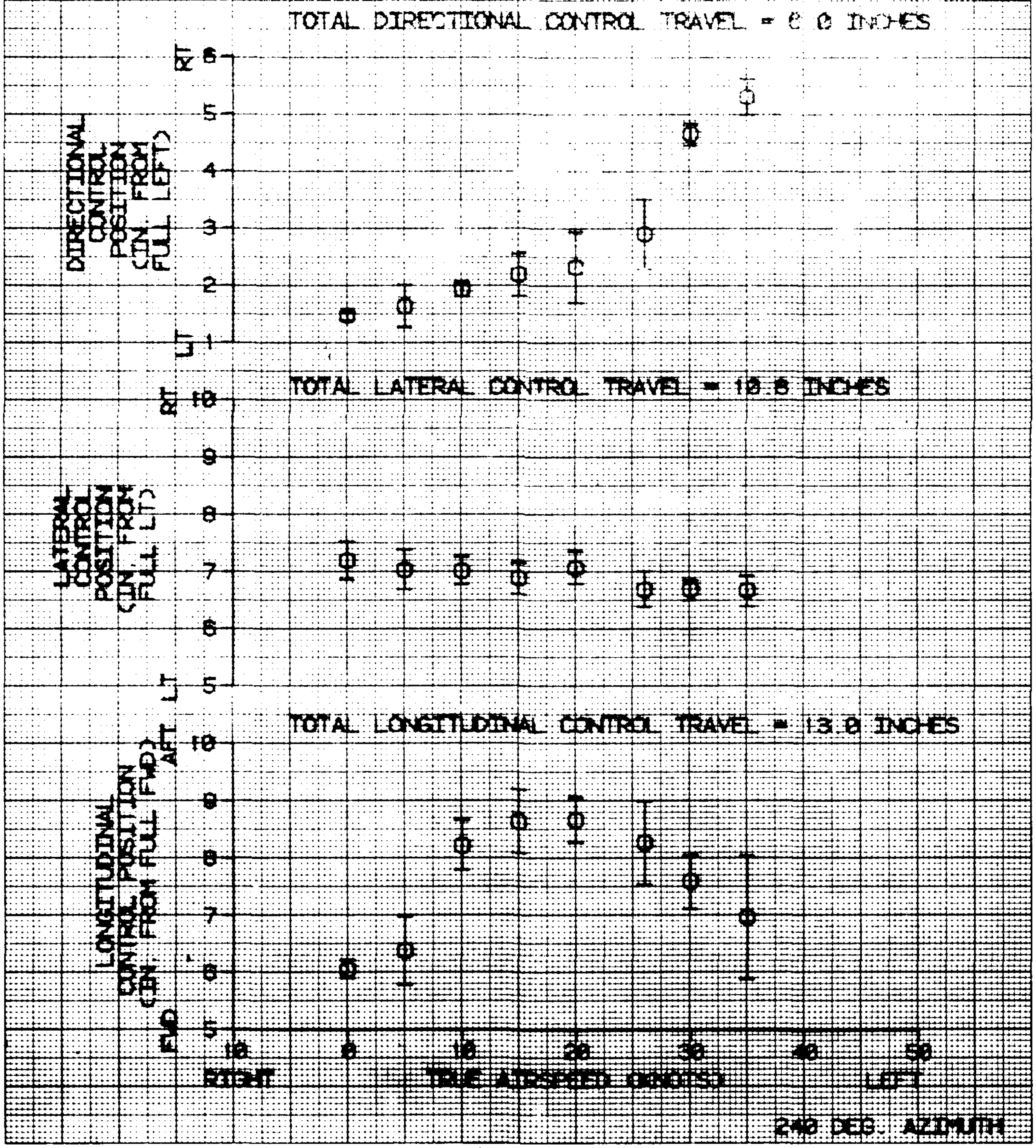
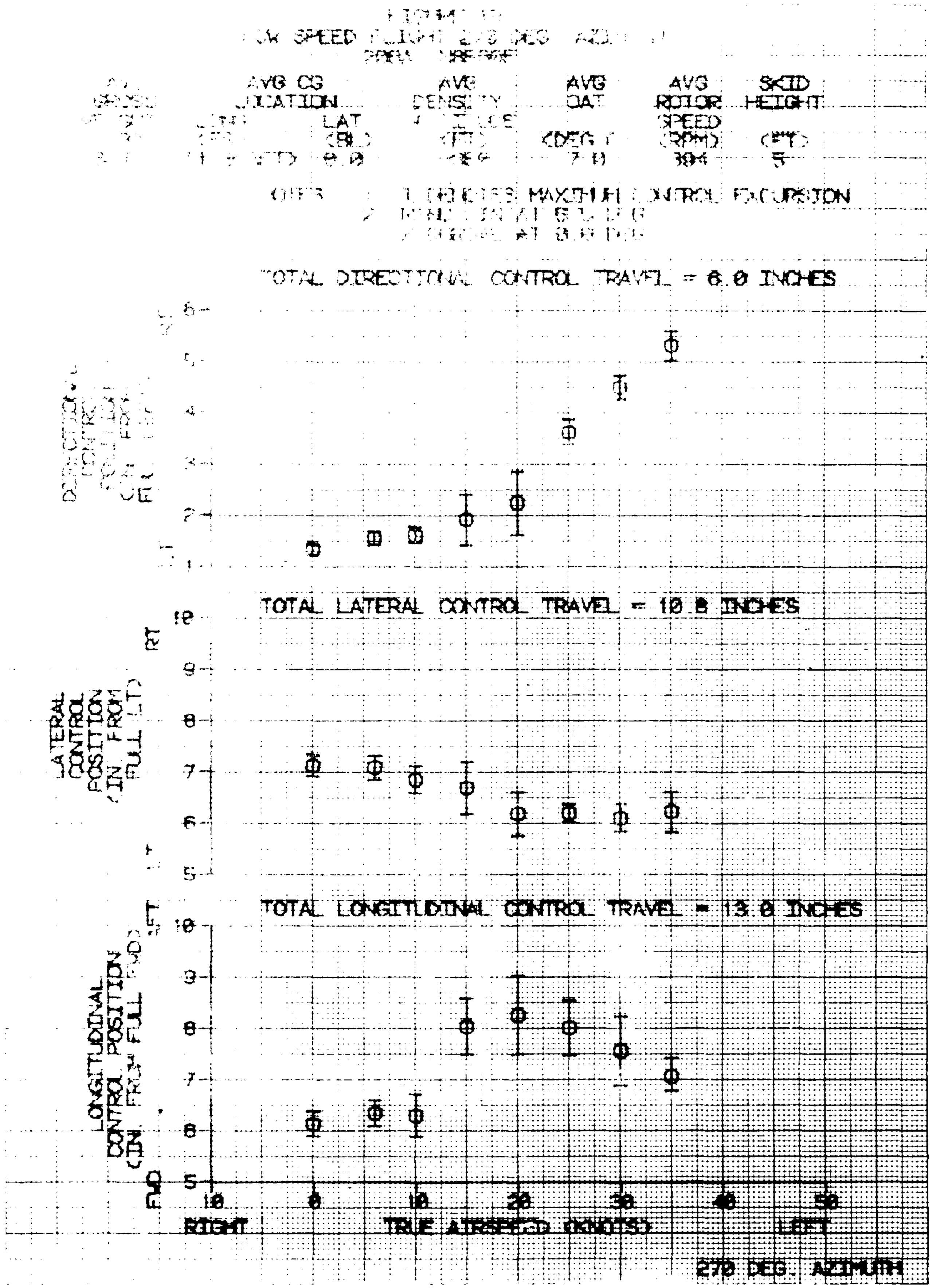


FIGURE 18
LOW SPEED FLIGHT 240 DEG. AZIMUTH
206A N8560F

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)
3190	111.0(AFT)	0.0	-350	7.0	394	5

NOTES: 1. I DENOTES MAXIMUM CONTROL EXCURSION
2. RING FIN AT 6.5 DEG
/ DORSAL AT 0.0 DEG.





AVG CG LOCATION
LAT (BL) 0.0
AVG DENSITY
AVG OAT (DEG C) 7.0
AVG ROTOR SPEED (RPM) 394
SKID HEIGHT (FT) 5
TOTAL DIRECTIONAL CONTROL TRAVEL = 6.0 INCHES
TOTAL LATERAL CONTROL TRAVEL = 10.8 INCHES
LATERAL CONTROL POSITION (IN. FROM FULL LT)
RT
TOTAL LONGITUDINAL CONTROL TRAVEL = 13.0 INCHES
LONGITUDINAL CONTROL POSITION (IN. FROM FULL FWD)
FWD
RIGHT
TRUE AIRSPEED (KNOTS)
LEFT
270 DEG. AZIMUTH

DISTRIBUTION

HQDA (DALO-SMM, DALO-AV, DALO-RQ, DAMO-HRS, DAMA-PPM-T, DAMA-RA, DAMA-WSA, DACA-EA)	8
US Army Materiel Command (AMCDE-SA, AMCQA-E, AMCDE-I, AMCDE-P, AMCQA-SA, AMCSM-WA AMCQA-ST)	7
US Army Training and Doctrine Command (ATTG-U, ATCD-T, ATCD-ET, ATCD-B)	4
US Army Aviation Systems Command (AMSAV-ED, AMSAV-EI, AMSAV-EL, AMSAV-EA, AMSAV-EP, AMSAV-ES, AMSAV-Q, AMSAV-MC, AMSAV-ME)	11
US Army Test and Evaluation Command (AMSTE-CT-A, AMSTE-TO-O)	2
US Army Logistics Evaluation Agency (DALO-LEI)	1
US Army Materiel Systems Analysis Agency (AMXSY-R, AMXSY-MP)	2
US Army Operational Test and Evaluation Agency (CSTE-ASD-E)	1
US Army Armor Center (ATZK-CD-TE)	1
US Army Aviation Center (ATZQ-D-T, ATZQ-TSM-A, ATZQ-TSM-S, ATZQ-TSM-U)	4
US Army Combined Arms Center (ATZLCA-DM)	1
US Army Safety Center (PESC-Z, PESC-Library)	2
US Army Research and Technology Laboratories (AVSCOM) (SAVDL-AS, SAVDL-POM (Library))	2
US Army Research and Technology Laboratories/Applied Technology Laboratory (SAVDL-ATL-D, SAVDL-Library)	2
US Army Research and Technology Laboratories/Aeromechanics Laboratory (AVSCOM) (SAVDL-AL-D)	1

US Army Research and Technology Laboratories/Proplusion Laboratory (AVSCOM) (SAVDL-PL-D)	1
Defense Technical Information Center (DDR)	12
US Military Academy, Department of Mechanics (Aero Group Director)	1
MTMC-TEA (MTT-TRC)	1
ASD/AFXT, ASD/ENF	2
US Naval Post Graduate School, Department Aero Engineering (Professor Donald Layton)	1
Assistant Technical Director for Projects, Code: CT-24 (Mr. Joseph Dunn)	2
6520 Test Group (ENML/Stop 238)	1
Commander, Naval Air Systems Command (AIR 5115B, AIR 5301)	3
Defense Intelligence Agency (DIA-DT-20)	1
Director, US Army Aviation Applied Technology Directorate (SAVRT-TY-ATA (Mr. Smith))	5
Bell Helicopter Textron, Inc. (Harry Harr)	5
Project Manager, Advanced Scout Helicopter (AMCPM-ASH)	5
Commander, US Army Aviation Systems Command (AMSAV-LU)	3

END
FILMED
4-86
DTIC